

VIDEO IDENTIFICATION OF BOREAL FOREST SONGBIRD NEST PREDATORS AND DISCORDANCE WITH ARTIFICIAL NEST STUDIES

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Abstract. Increased rates of nest predation in human-modified landscapes are considered a major cause of declining numbers of some North American songbird species. However, conservation efforts in many regions are hampered by limited knowledge of which predators are chiefly responsible for nest failure. This is particularly true for the boreal forest where our current understanding of the nest predator community is based almost entirely on artificial nests. We used an infrared digital video system to document which predators destroyed real nests in two boreal forest landscapes that differed in their amount of edge habitat and in their proximity to agriculture. We compared these results to the predator communities identified in three artificial nest studies conducted in habitats similar to ours to determine whether this commonly used technique accurately represented the dominant predators of real nests. Our video data revealed that all predators of real nests were species commonly associated with the boreal forest. This was contrary to our prediction that human-associated nest predators would be detected in the site with more edge habitat that was closer to agriculture. Our video data also revealed that the predators of real and artificial nests differed and we caution researchers in drawing conclusions about nest predation of boreal forest songbirds based on artificial nests.

Key Words: boreal forest songbird, nest predation, artificial nest, edge effect, video monitoring, red squirrel, Gray Jay.

IDENTIFICATION VIDÉO DES PRÉDATEURS DE NICHÉES DE PASSEREAUX DE LA FORÊT BORÉALE ET LA DISCORDANCE AVEC LES ÉTUDES AYANT UTILISÉ DES NIDS ARTIFICIELS

Résumé. Des taux de prédation plus élevés dans les paysages modifiés par les humains sont considérés comme une des causes majeures d'une plus faible abondance chez certaines espèces de passereaux forestiers d'Amérique du Nord. Cependant, les efforts de conservation sont entravés par les connaissances limitées des prédateurs qui sont principalement responsables de la prédation des nids. Ceci est particulièrement vrai dans la forêt boréale où notre compréhension sur les communautés de prédateurs de nichées sont basées presque entièrement sur des études ayant utilisé des nids artificiels. Nous avons utilisé un système vidéo digital infrarouge afin de documenter quels prédateurs détruisent de vrais nids dans deux paysages boréaux qui diffèrent dans leur quantité d'habitat de bordures et dans leur proximité à des milieux agricoles. Nous avons comparé ces résultats aux communautés de prédateurs identifiées dans trois études ayant utilisé des nids artificiels et s'étant déroulées dans des habitats similaires au nôtre afin de déterminer si cette technique communément utilisée représente précisément les prédateurs dominants de vrais nids. Nos observations vidéo ont révélé que tous les prédateurs de vrais nids étaient des espèces associées à la forêt boréale. Ces résultats sont contraires à nos prédictions stipulant que les prédateurs de nichées associés aux humains seraient détectés dans le site avec plus d'habitat de bordures qui était à proximité de milieux agricoles. Nos observations vidéo révèlent également que les prédateurs de vrais nids et de nids artificiels diffèrent. Nous suggérons aux chercheurs de faire attention à leurs conclusions concernant la prédation des nichées de passereaux de la forêt boréale lorsqu'elles sont basées sur des études utilisant des nids artificiels.

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INTRODUCTION

Nest predation is a primary cause of reproductive failure in songbirds and increased rates of nest predation in fragmented habitats are considered a major cause of population declines in some North American songbird species (Robinson et al. 1995). Forest fragmentation creates edge habitat and it has been suggested that the diversity, density, and foraging intensity of nest predators increases in edge habitat, and that changed habitat conditions near edges make nests easier for predators to locate (Chalfoun et al. 2002). However, conservation efforts are often hampered by inadequate knowledge of the identities and relative contributions of nest predators in the community (Thompson 2007). This is particularly true in boreal forests where current understanding of the nest predator community is based almost entirely on artificial nest studies (e.g., Bayne and Hobson 1997, Song 1998, Cotterill and Hannon 1999), which likely do not reflect the relative importance of each nest predator species to the survival of real nests (Zanette 2002).

If the creation of edge alters the predation dynamics for passerine nests, it is important to clarify patterns of nest predation in songbird communities of Canada's boreal forest due to rapid increases in energy sector development and forestry activity in the last decade (Schneider et al. 2003). Local negative edge effects on nest success tend to be stronger in more fragmented landscapes (Driscoll and Donovan 2004) and in landscapes fragmented by agriculture, which may attract forest- and human-associated predators to edges by providing additional food sources (Chalfoun et al. 2002). This suggests boreal songbird nest fate may be particularly sensitive to intensive edge development along the southern forest-agriculture transition zone. Negative edge effects also are more commonly reported when avian species are important nest predators (Chalfoun et al. 2002). The role of avian nest predators in the boreal forest is not known. These uncertainties about the nest predator community must be addressed to enable predictions about the potential impact of future industrial development.

We designed an infrared digital video camera system to monitor nests and document the identities of nest predators in two boreal forest landscapes, a northern site with a single linear clearing bisecting otherwise contiguous forest, and a more southerly site with multiple linear clearings. We predicted that the nest predator community in the southern landscape would be more diverse and composed of more human-associated predators because it had more edge

habitat, it was closer to agricultural lands, and because we observed human-associated predators within or in close proximity to these study plots (J. Ball unpublished data). We compared our predator data from real, video-monitored nests to the predators identified in three separate boreal forest artificial nest studies to determine whether this commonly used technique accurately represents the dominant nest predators' influence on real nest success. The implications of our results for future industrial development indirectly affecting nesting boreal forest songbirds through increased rates of predation are discussed.

METHODS

STUDY AREAS

All nest predator data presented here was collected in boreal mixed wood forest stands in western Canada. Real nest data were collected as part of a larger research project on the impacts of energy sector activity on forest songbird communities. Study plots were established in association with energy sector linear features (i.e., pipelines, seismic lines, and limited-use service roads). We focused on linear features to minimize confounding edge-associated effects with additional effects associated with habitat loss and adjacent habitat type (e.g., forestry cut blocks or agriculture) and additional effects from high-use roads (e.g., vehicle mortalities and vegetation dusting). The energy sector linear features in our study can be generally characterized as open, straight corridors that often extend tens to hundreds of kilometers. In regions of high energy sector activity, these linear features periodically intersect creating a network of open corridors. Pipelines were typically 25 m wide, seismic lines were typically 8 m wide, and service roads ranged between 12 and 25 m in width. Most lines were kept free of extensive woody vegetation by periodic clearing and by occasional all-terrain vehicle use.

Real nest data were collected from two regions (Fig. 1). Six 42-ha plots were established at a northern site near Fort Simpson, NT (61°52'N, 121°20'W) in 2005 and 2006. Each Fort Simpson plot was adjacent to a single linear feature (hereafter low-impact site). Seven 24-ha plots were established at a southern site in the Chinchaga Forestry Region, AB (57°18'N, 118°23'W) in 2006. Two additional plots were added to the Chinchaga site in 2007 for a total of nine plots. Each Chinchaga plot (hereafter high-impact site) was bordered by one or two linear clearings and each was bisected by one or more additional linear clearings. Each plot was

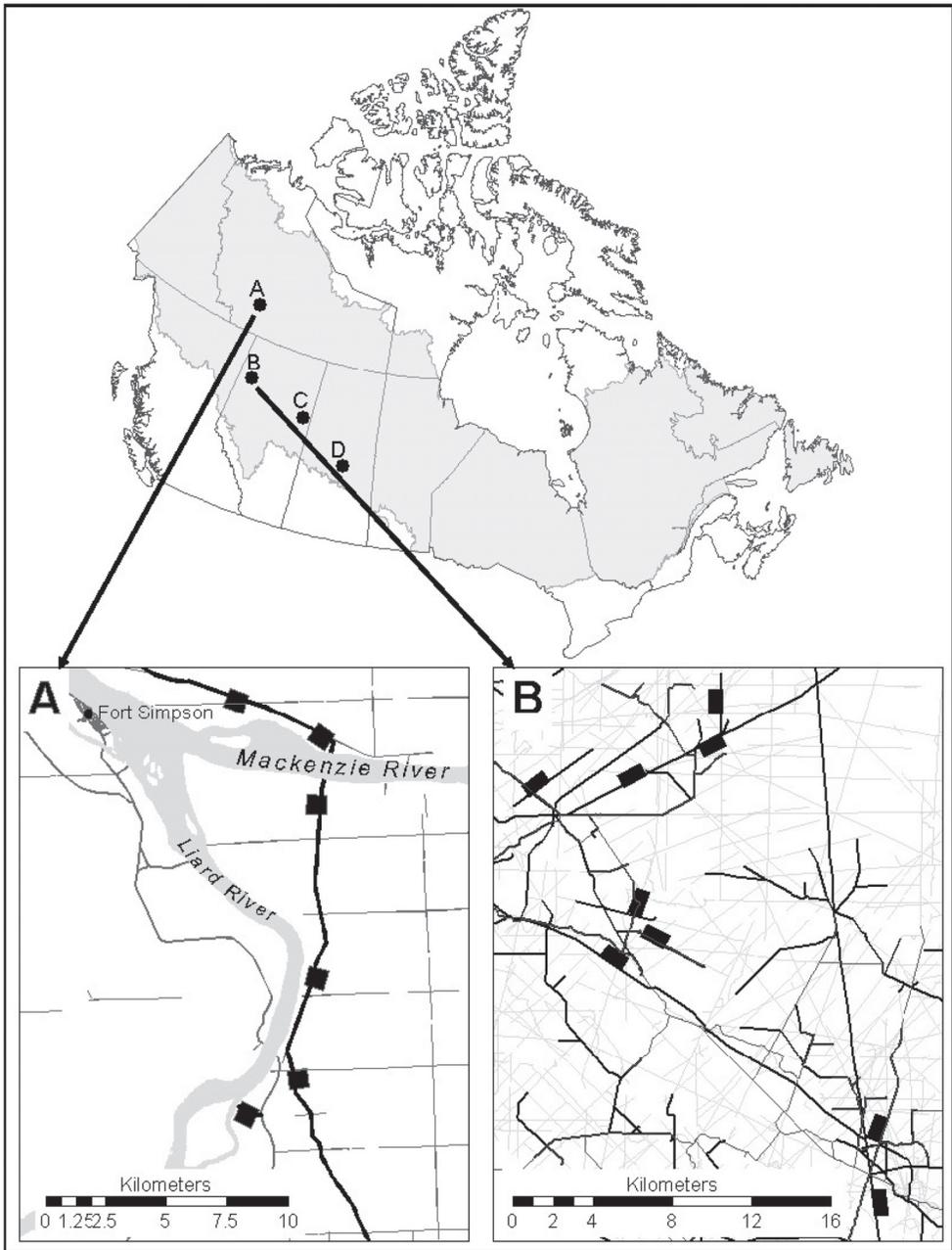


FIGURE 1. Real nest data were collected from Fort Simpson, NT (point A on upper panel, lower left detailed view), and from the Chinchaga Forestry Region, AB (point B on upper panel, lower right detailed view). Real nest study plots (black boxes on two lower panels) were bordered by one or more (Chinchaga only) wide pipelines and/or service roads (dark lines) and may have been bisected by one or more narrower seismic lines (grey lines). Artificial nest data were collected from Fort Simpson, NT (point A), NE Alberta between Lac la Biche and Fort McMurray (point C), and Prince Albert National Park, SK (point D). The spatial extent of the boreal forest in Canada (shaded portion of the upper panel) is from The Canadian BEACONS Project <<http://www.beaconsproject.ca/map.htm>> (accessed January 31, 2009).

located a minimum of 1.2 km (high-impact site) to 2 km (low-impact site) from other plots. Plot sizes and inter-plot distances were chosen to minimize the likelihood that smaller predators would predate all nests on a single plot or that large predators would predate multiple plots (Donovan et al. 1997, Stephens et al. 2003).

We compiled artificial nest data from three separate studies conducted between 1994 and 2005 (Fig. 1): Prince Albert National Park, SK (Bayne and Hobson 1997); NE Alberta between Lac la Biche and Fort McMurray (E. M. Bayne unpublished data); and Fort Simpson, NT (E. M. Bayne and S. J. Hartfeil unpublished data). We selected a subsample of artificial nests to enable valid comparisons to data collected on real nests. The Prince Albert data included nests from contiguous and harvested forests but excluded nests from farm woodlots. The NE Alberta data excluded transects associated with public gravel roads. The Fort Simpson data excluded a large number of additional nests placed directly on the pipeline for a separate experiment comparing forest vs. pipeline nest fate. Compared to all other study sites included here, the NE Alberta sites were more dominated by deciduous habitats.

REAL NESTS

Predators of real nests were identified using an infrared video system that provided 24-hour surveillance at four nests simultaneously, without continual observer interference. Cameras were small (8 cm long x 3.5 cm in diameter), and each was mounted in vegetation approximately 0.5 m from the nest. Cameras were targeted at Swainson's Thrush (*Catharus ustulatus*) and Chipping Sparrow (*Spizella passerina*) nests when possible for a concurrent study of parental nesting behavior. Cameras were placed at nests of other ground or shrub-nesting species when a suitable nest of either target species was unavailable. All video footage was viewed in the lab to determine the fate of each egg and nestling, and to identify nest predators.

ARTIFICIAL NESTS

One plasticine egg and one quail egg were placed in a wicker nest basket lined with vegetation. In Prince Albert and NE Alberta, nests were placed every 30 to 40 m along transects established parallel to the forest edge. Nests on edge transects were within 5 m of the forest edge. Nests on interior transects were approximately 300 m from the forest edge. The artificial nest study in Fort Simpson was conducted on the same plots as the real nest study. Nests

were placed at randomly selected distances (between 1 and 100 m) and bearings from stations located 0, 200, and 400 m from the forest edge. Unlike Prince Albert and NE Alberta, the Fort Simpson data included some nests that were located directly on a clearing. In all three studies, each nest was alternately assigned to a shrub or ground category and placed in a micro-habitat similar to a real nest (Bayne et al. 1997). Nests were placed during the peak breeding season (late May to mid-July) and left in place for approximately 10 days to simulate a typical songbird incubation period.

Because we were interested in comparing the predator communities of real and artificial nests, we focused on the fate of the plasticine egg, which allowed us to identify predators based on the size and shape of impressions left in the plasticine. Predators were classified as sciurid, corvid, large mammal, small mammal, raptor, and unknown. Missing artificial eggs (44% of depredated nests) were placed into one of these predator categories based on the relative abundance of each predator (determined from the number of confirmed predations by each predator in each study) and the tendency of each predator to remove eggs (Bayne and Hobson 1999).

RESULTS

REAL NESTS

Video cameras were established at 175 nests, representing 15 songbird species (Table 1). In total, 122 (70%) monitored nests were above-ground (i.e., shrub or canopy) and the remainder were ground nests. The average (± 1 SD) nest distance from the forest edge was 117 ± 130 m (nests on a linear feature have a distance of zero). The majority of cameras (101 of 175) were established at nests within 80 m of the forest edge. These included 17 nests that were 0 m from the forest edge and were either located on or adjacent to a linear clearing.

Seventy-three predators were recorded at 71 nests during four field seasons (Fig. 2). Video monitoring confirmed that all nest predators were species typically associated with the boreal forest. Red squirrels (*Tamiasciurus hudsonicus*) were the dominant predator in both study sites, taking nests or eggs in 45% to 84% of the video-monitored nests annually. Two nests, one partially depredated by a Sharp-shinned Hawk (*Accipiter striatus*) and another partially depredated by a red-backed vole (*Clethrionomys gapperi*), were subsequently depredated by a red-squirrel. Sharp-shinned Hawks were another important predator in both study sites,

TABLE 1. THE NUMBER OF NESTS OF EACH SONGBIRD SPECIES THAT WERE MONITORED USING INFRARED DIGITAL VIDEO CAMERAS DURING EACH YEAR OF STUDY IN BOREAL MIXED WOOD FORESTS NEAR FORT SIMPSON, NT, AND IN THE CHINCHAGA FORESTRY REGION, AB.

Common name	Species name	Fort Simpson, NT		Chinchaga, AB	
		2005	2006	2006	2007
American Redstart	<i>Setophaga ruticilla</i>	2	1	-	1
American Robin	<i>Turdus migratorius</i>	1	1	1	2
Black-and-white Warbler	<i>Mniotilta varia</i>	1	-	-	-
Chipping Sparrow	<i>Spizilla passerina</i>	-	1	10	18
Dark-eyed Junco	<i>Junco Hyemalis</i>	1	-	1	6
Hermit Thrush	<i>Catharus guttatus</i>	3	7	-	-
Least Flycatcher	<i>Empidonax minimus</i>	2	-	-	1
Magnolia Warbler	<i>Dendroica magnolia</i>	1	-	-	1
Northern Waterthrush	<i>Seirus noveboracensis</i>	1	-	-	-
Ovenbird	<i>Seirus aurocapilla</i>	1	-	3	9
Swainson’s Thrush	<i>Catharus ustulatus</i>	20	24	4	26
Tennessee Warbler	<i>Vermivora peregrina</i>	4	3	2	6
White-throated Sparrow	<i>Zonotrichia albicollis</i>	2	1	1	1
Yellow-bellied Sapsucker	<i>Sphyrapicus varius</i>	-	-	1	-
Yellow-rumped Warbler	<i>Dendroica coronata</i>	1	-	1	2
TOTAL		40	38	24	73

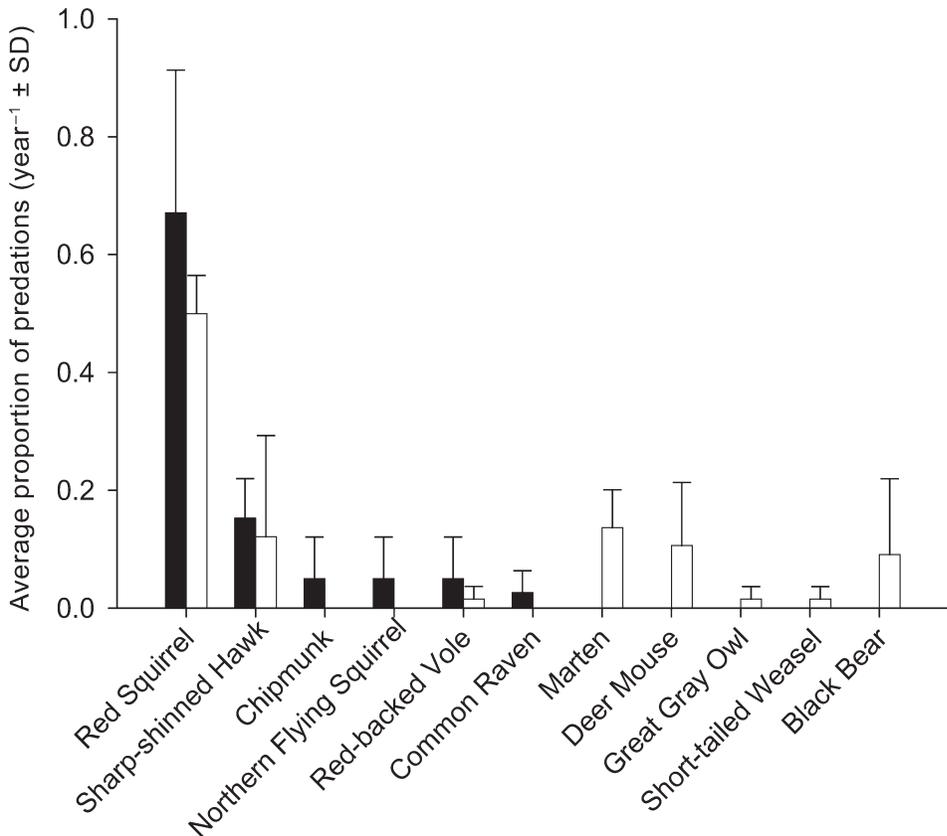


FIGURE 2. Proportion of video nests depredated by identified predator species in Fort Simpson, NT (black bars), and the Chinchaga Forestry Region, AB (white bars). Numbers of predators recorded by study site and year were NT 2005 = 10, NT 2006 = 19, AB 2006 = 11, AB 2007 = 33.

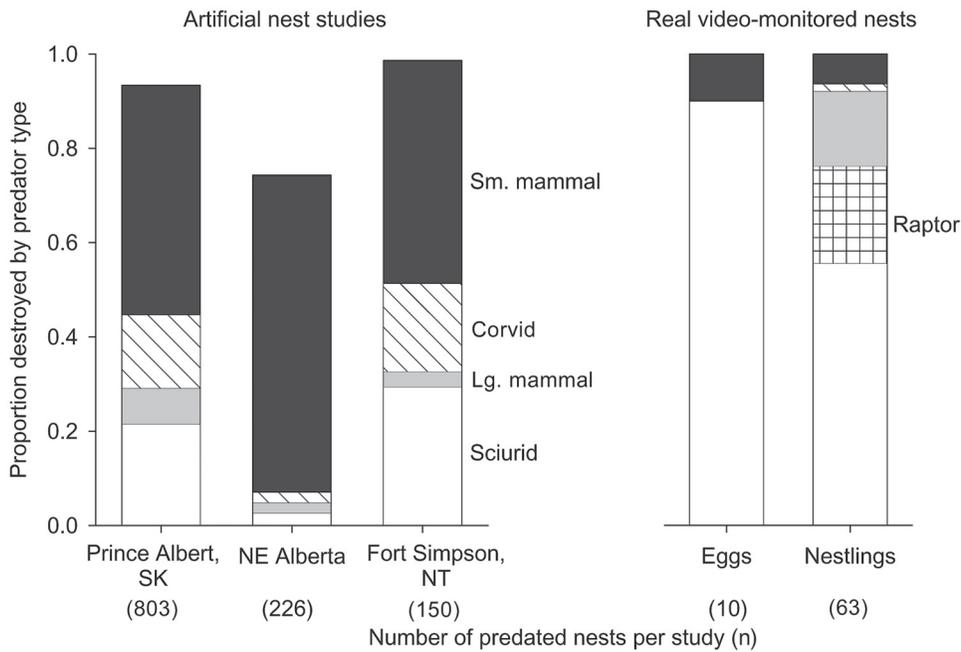


FIGURE 3. Proportion of real nests (either nestlings or eggs; total number of nests reported in brackets) or artificial nests (by study location) depredated by each identified predator category (labeled on the graph). Predators of artificial nests identified as 'unknown' are not shown. The difference in height of the artificial nest bars from 1.0 indicates the proportion of nests where the predator was identified as 'unknown'.

depredating up to 24% of video-monitored nests in the high-impact site during 2007. Other important nest predators in the high-impact site (>10% of video nests destroyed in a given year) included deer mice (*Peromyscus maniculatus*), American black bear (*Ursus americanus*), and American marten (*Martes americana*).

Overall, the diversity of nest predators in the low- and high-impact sites was similar (six vs. eight species, respectively). However, in the high-impact site, the importance of some species as nest predators varied between years. For example, deer mice and black bear each destroyed two of the 11 depredated video nests in 2006 but only one and zero, respectively, of the 33 depredated nests in 2007. Similarly, marten and Sharp-shinned Hawks destroyed one and zero video nests, respectively, in 2006 but six and eight nests in 2007.

ARTIFICIAL NESTS

A total 2849 artificial nests were set out (Prince Albert = 1647, NE Alberta = 607, Fort Simpson = 595). Of these, 1179 nests were destroyed by identifiable predators (Fig. 3). Small mammals were the dominant predator of artificial nests in all study areas. Corvids and sciurids were also important artificial nest

predators in Prince Albert (16% and 22% of destroyed nests, respectively) and Fort Simpson (19% and 29%, respectively). The importance of small mammals and near-absence of sciurid predations in NE Alberta compared to the other artificial nest studies (Fig. 3) likely reflects the dominant deciduous composition of those forest stands.

ARTIFICIAL NESTS VERSUS REAL NESTS

The predators of artificial and real nests differed in diversity and relative importance (Fig. 3). Small mammals had a large impact on artificial nest failure (47% to 67% of destroyed nests), but they were relatively unimportant to real nest fate (6% to 10% of depredated nestlings and eggs, respectively). Similarly, corvids were important artificial nest predators in two of three study sites, but they were unimportant real nest predators (2% of depredated nestlings). In contrast, sciurids, which were the dominant predator of real nests (56% to 90% of depredated nestlings and eggs, respectively), were relatively less important to artificial nest fate. Finally, artificial nests did not identify raptors as important nest predators.

Our approach of assigning missing plasticine eggs to predator categories (see Methods)

assumed that the composition of the predator categories and the tendency for each predator to remove eggs was similar across the regions where artificial nest studies were performed. When we excluded missing eggs and only considered identified predators, the differences among predators and between artificial nests and real nests remained and, in most cases, were exaggerated further. Small mammals became relatively more important to nest fate whereas sciurids, corvids, and large mammals became less important.

DISCUSSION

Contrary to our prediction, the identified predator community of real nests in the high-impact Alberta site was similar to that of the low-impact Northwest Territories site, both of which were characterized by boreal forest-associated species only. This result was surprising given the higher density of edge habitat, increased proximity to agricultural areas, and the observed presence of potential human-associated nest predators in Alberta. For example, we observed coyotes (*Canis latrans*), white-tailed deer (*Odocoileus virginianus*), and American Crows (*Corvus brachyrhynchos*) near or within our Alberta study plots. However, these species were rarely observed compared to forest-associated predators (J. Ball unpublished data) and our study plots may be too far from agricultural areas for these species to have important effects on nest fate (Lloyd et al. 2005).

Our video data demonstrate that predators of real and artificial nests differed (Fig. 3). First, predator diversity differed between the two nest types. The artificial nest studies failed to document raptors as nest predators, because raptors only depredate nestlings (21% of nestling predations). Second, predators differed in relative importance between the two nest types. Our video data confirmed that small mammals can and do depredate real nests. However, together with corvids, their relative importance as nest predators (<10% combined) is over-emphasized by artificial nest studies. In contrast, sciurids, which depredated nearly twice as many nestlings and more than triple the number of real eggs compared to artificial eggs, are under-represented by artificial nest studies.

We expected corvids to be important predators in our real nest study. Gray Jays (*Perisoreus canadensis*) are a common corvid in the boreal forest and they are widely considered important nest predators that are attracted to forest edges (Ibarzabal and Desrochers 2004). However, their importance as nest predators is based largely on artificial nest studies (summarized by

Ibarzabal and Desrochers 2004) and anecdotal observations (Ouellet 1970). We did not record Gray Jay predation of any real nests although we identified Gray Jays as important artificial nest predators and we frequently encountered individuals and family groups on our real nest plots (J. Ball unpublished data). This suggests corvids may be less important nest predators than previously thought. Because corvids are visual predators, real nests may be more cryptic than artificial nests, and adult songbirds may provide an effective defense. We join Zanette (2002) in cautioning researchers in drawing conclusions about nest predation rates and predator identity based on artificial nests without validating this technique in their system.

Negative edge effects are more commonly reported along forest-field ecotones (Batary and Baldi 2004), or when avian, rather than mammalian species, are the predominant nest predator (Chalfoun et al. 2002). We did not identify human-associated species or Gray Jays depredating real nests. This suggests that much of Canada's boreal forest may not be vulnerable to some of the more commonly cited negative effects associated with edges because it is sufficiently far from agriculture and because Gray Jays are not as important a nest predator as previously believed. Our nest survival data support this conclusion. We found that nest survival probability did not differ between the low- and high-impact sites, and that the survival probability of ground nests was higher near the edge compared to the forest interior in both sites (Ball et al. 2009). Seismic lines and pipelines effects on boreal forest songbird populations appear to be primarily through direct loss of forest habitat rather than indirect, edge-induced decreases in reproductive success (Bayne et al. 2005).

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LITERATURE CITED

- BALL, J. R., E. M. BAYNE, AND C. S. MACHTANS. 2009. Energy sector edge effects on songbird nest fate and nest productivity in the boreal forest of western Canada: a preliminary analysis, pp. 161-170. *In* T. D. Rich, C. Arizmendi, D. W. Demarest, and C. Thompson [eds.], *Tundra to Tropics: Connecting Birds, Habitats and People*. Proceedings of the 4th International Partners in Flight Conference, 13-16 February 2008. McAllen, TX. Partners in Flight.
- BATARY, P., AND A. BALDI. 2004. Evidence of an edge effect on avian nesting success. *Conservation Biology* 18:389-400.
- BAYNE, E. M., AND K. A. HOBSON. 1997. Comparing the effects of landscape fragmentation by forestry and agriculture on predation of artificial nests. *Conservation Biology* 11:1418-1429.
- BAYNE, E. M., AND K. A. HOBSON. 1999. Do clay eggs attract predators to artificial nests? *Journal of Field Ornithology* 70:1-7.
- BAYNE, E. M., K. A. HOBSON, AND P. FARGEY. 1997. Predation on artificial nests in relation to forest type: contrasting the use of quail and plasticine eggs. *Ecography* 20:233-239.
- BAYNE, E. M., S. L. VAN WILGENBURG, S. BOUTIN, AND K. A. HOBSON. 2005. Modeling and field-testing of Ovenbird (*Seiurus aurocapilla*) responses to boreal forest dissection by energy sector development at multiple spatial scales. *Landscape Ecology* 20:203-216.
- CHALFOUN, A. D., F. R. THOMPSON III, AND M. J. RATNASWAMY. 2002. Nest predators and fragmentation: a review and meta-analysis. *Conservation Biology* 16:306-318.
- COTTERILL, S. E., AND S. J. HANNON. 1999. No evidence of short-term effects of clear-cutting on artificial nest predation in boreal mixed-wood forests. *Canadian Journal of Forest Research* 29:1900-1910.
- DONOVAN, T. M., P. W. JONES, E. M. ANNAND, AND F. R. THOMPSON III. 1997. Variation in local-scale edge effects: mechanisms and landscape context. *Ecology* 78:2064-2075.
- DRISCOLL, M. J., AND T. M. DONOVAN. 2004. Landscape context moderates edge effects: nesting success of Wood Thrush in central New York. *Conservation Biology* 18:1330-1338.
- IBARZABAL, J., AND A. DESROCHERS. 2004. A nest predator's view of a managed forest: Gray Jay (*Perisoreus canadensis*) movement patterns in response to forest edges. *Auk* 121:162-169.
- LLOYD, P., T. E. MARTIN, R. L. REDMOND, U. LANGNER, AND M. M. HART. 2005. Linking demographic effects of habitat fragmentation across landscapes to continental source-sink dynamics. *Ecological Applications* 15:1504-1514.
- OUELLET, H. 1970. Further observations on the food and predatory habits of the Gray Jay. *Canadian Journal of Zoology* 48:327-330.
- ROBINSON, S. K., F. R. THOMPSON III, T. M. DONOVAN, D. R. WHITEHEAD, AND J. FAABORG. 1995. Regional forest fragmentation and the nesting success of migratory birds. *Science* 267:1987-1990.
- SCHNEIDER, R. R., J. B. STELFOX, S. BOUTIN, AND S. WASEL. 2003. Managing the cumulative impacts of land uses in the western Canadian sedimentary basin: a modelling approach. [Online.] *Conservation Ecology* 7:8 <<http://www.consecol.org/vol7/iss1/art8>> (15 May 2008).
- SONG, S. J. 1998. Effects of natural and anthropogenic forest edge on songbirds breeding in the boreal mixed-wood forest of northern Alberta. Ph.D. thesis, University of Alberta, Edmonton, AB.
- STEPHENS, S. E., D. N. KOONS, J. J. ROTELLA, AND D. W. WILLEY. 2003. Effects of habitat fragmentation on avian nesting success: a review of the evidence at multiple spatial scales. *Biological Conservation* 115:101-110.
- THOMPSON, F. R., III. 2007. Factors affecting nest predation on forest songbirds in North America. *Ibis* 149:98-109.
- ZANETTE, L. 2002. What do artificial nests tell us about nest predation? *Biological Conservation* 103:323-329.