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Effects of Pipeline Rights-of-Way on Forest Birds in the Boreal Forest of Alberta

by

Warren D. Fleming

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment
of the requirements for the degree of Master of Science

in

Wildlife Ecology and Management

Deparment of Renewable Resources

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ABSTRACT

I conducted a two year field study to measure the local effects of pipeline rights-of-way (RoW) on forest songbirds in the boreal forest south of Grande Prairie, Alberta. Neither the presence of RoW, nor RoW width, affected bird species richness in the adjacent forest. However, I found some differences in bird community composition in forests near edges of pipeline RoW when compared to control sites, with most affected species more abundant at edges than in the controls. Depredation of artificial shrub nests was significantly higher adjacent to wide RoW when compared to narrow ones, possibly a result of small mammals exploiting the grassland type habitat within RoW. Construction of pipeline RoW in the future should focus on reducing RoW width whenever possible, and consider leaving forested corridors across them to facilitate wildlife movement. Future research must address the landscape-level consequences of pipeline RoW and related developments (e.g., seismic lines, roads and wellsites).

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Chapter 1: Introduction

1.1 Background:

Over the past decade, there has been a dramatic expansion of industrial activity in the boreal forests of Alberta (Schmiegelow and Hannon 1993, AEP 1998). New found value of deciduous tree species such as trembling aspen (*Populus tremuloides*) and balsam poplar (*P. balsamifera*), which dominate much of the boreal mixedwood forest, has increased logging pressure (Marchak 1995), and oil and gas interests continue to look for new energy sources throughout the region. New energy finds require the construction of roads, wellsites and pipelines, adding infrastructure to an already developed and fragmented landscape (AEP 1998). This industrial activity contributes to loss and degradation of habitat for wildlife species that inhabit the region. At present, there is insufficient knowledge about wildlife habitat requirements of species found in the boreal forest to make informed management decisions (Schmiegelow and Hannon 1993). Cooperative research is required to determine how various wildlife species are affected by disturbances associated with industry, as the opportunity exists to manage such disturbances more effectively, given appropriate information. In this research, birds were studied to assess the utility of habitat both in, and adjacent to, forest dividing corridors created by oil and gas exploration and development, and to determine whether these corridors are contributing to habitat loss and fragmentation. A controlled field study was conducted in the boreal forest ecotype of Alberta on and adjacent to pipeline rights-of-way (RoW) of various widths in 1998 and1999. This research will provide information about management options for pipeline companies and will be valuable for use in cumulative effects assessment.

1.2 Forest Fragmentation and Habitat Loss:

Fragmentation is a landscape level process (Fahrig 1999) that involves the separation of large contiguous areas of habitat into smaller and more isolated 'islands' of habitat, by means of natural or human caused disturbance events (e.g., McComb 1999). Fragmentation based theories of species abundance have their roots in the theory of island biogeography (MacArthur and Wilson 1967), and metapopulation theory (Levins 1970). These theories, and much of the literature since published on fragmentation, use the sizes and proximity of habitat patches within a landscape to make predictions about the number of species that will be present in those habitat patches (Ambuel and Temple 1983, Bancroft et al. 1995, Hagan et al. 1996).

In the case of forests, fragmentation is inextricably linked to removal of habitat (Fahrig 1999), and much related literature considers fragmentation and habitat loss as a combined process, under the heading of fragmentation. This has resulted in a greater emphasis being placed on how remaining habitat is configured, and how to maintain connectivity between remaining habitat, rather than on the actual amount of habitat available (Fahrig 1999). However, habitat loss is considered to be the most important factor contributing to the current extinction crisis around the world (Groomsbridge 1992, Bibby 1995, Ehrlich 1995, Thomas and Morris 1995).

Disturbance events occur naturally in all types of forest, and range greatly in size and intensity, from individual trees dying or falling, to wildfires consuming thousands of hectares. Human activity, however, inflicts on the landscape a scale of disturbance that often exceeds natural disturbance levels. Such human activities may change the composition and structure of forests and the effects that this can have on wildlife species, both from direct habitat loss and from habitat fragmentation, are poorly understood.

Much of the research carried out to address these issues in North America has been conducted in the Eastern part of the continent, in landscapes which usually consist of small patches of forest embedded in a largely agricultural matrix. There is often large separation between areas of habitat that are available for species that depend on forest habitat for survival. The results of this research may not apply to areas in the boreal forest, where the disturbances created by the forestry and oil and gas industries are usually embedded in a forested landscape.

Many studies conducted in North America have indicated that forest fragmentation, and associated edge effects, are adversely affecting wildlife. For example, Ambuel and Temple (1983) found that bird diversity in larger woodlots was higher than that in small ones, due to increases in the number of forest dwelling neotropical migrants. Several species of birds in deciduous forests in the Florida keys had lower abundance, or were not present at all, in small woodlots, suggesting that effective habitat loss for these area-dependent species far exceeded the actual loss of forest (Bancroft et al. 1995). In recently fragmented forests in the state of Maine, some typically forest dependent species of birds were actually found to be more abundant in forest fragments for up to 200 days following forest harvest, probably from overcrowding of birds displaced from the harvest area (Hagan et al. 1996). Pairing success in ovenbirds (*Seiurus aurocapillus*), however, was lower in fragments despite the increased abundance. This may be due to behavioral dysfunction resulting from the higher densities (Hagan et al. 1996). American marten (*Martes americana*) are sensitive to several indices of fragmentation on different ecological scales (Bissonette 1997). For example, marten found in fragmented habitats required home ranges twice as large as those in unfragmented areas (Potvin and Breton 1997). Most of this research reflects an emphasis on patch size and configuration, and has generally been carried out in agriculture dominated areas. There remains a need to gain information on how anthropogenic disturbances associated with industry in the boreal forest are contributing to habitat loss and degradation for forest dwelling species and species assemblages.

1.3 Edge Effects:

The loss of habitat caused by linear features can be exacerbated by the creation of 'edge' habitat. Edge habitat is defined as that area adjacent to the edge of a forest where conditions exist that change the suitability of habitat near the boundary, both for forest specialist species, and other species that may move into the disturbed area (e.g., Odum 1971). As a result of the merging of two conspicuous habitat types, this edge habitat is generally considered to have increased numbers and diversity of organisms (Gates and Gysel 1978). However, the different conditions found at or near edges, can result in deleterious changes to adjacent forests for species that prefer or require interior forest habitat (Bancroft et al. 1995, Reed et al. 1996). There are several known edge effects that could affect boreal forest birds, each of which is discussed here.

1.3.1 Edge avoidance/attraction:

Some species of forest birds will simply not attempt to breed within a certain distance of a forest edge. The conditions created by an edge result in unsuitable habitat, possibly because of changes in plant community, changes in microclimate, i.e. wind, light or temperature, or changes in the animal communities associated with the edge and the neighboring habitat (e.g., Kroodsma 1982a, Ambuel and Temple 1983). This does not necessarily result in lower overall species diversity near the edge because of the increase in species associated with open areas, but may result in a lower density of species associated with old growth forest (Anderson et al. 1977, Kroodsma 1982b).

In forest areas near edges, bird species not typically associated with forests may become more abundant (Rich et al. 1994, Schieck et al. 1995). This phenomenon could result in increased competition for forest dependent species, as well as increased predation rates and brood parasitism (see below). All of these effects decrease the likelihood that nests of forest nesting passerine birds will be successful, possibly to the point of creating a population sink, or ecological trap, for some (e.g., Gates and Gysel 1978).

1.3.2 Predation:

Forest nesting birds that do not avoid edges, whether by choice or because of lack of more suitable habitat, may be affected by other factors associated with edge. One of those factors is an increase in predation, both on adult birds and on the eggs and young birds in the nest. Edges of forest that border on open land are associated with an increase in many species of animals that are known to prey on birds and bird nests. These species include many corvids (i.e. jays, crows and magpies), some raptor species, raccoons, foxes, skunks, chipmunks, squirrels and mice. This increase in potential predators has been associated with an increase in predation rates on birds (Ambuel and Temple 1983, Wilcove 1985). There is, however, some recent controversy about the actual extent of this effect on forest nesting birds. Haskell (1995) has suggested that experimental techniques used in past studies of nest predation have a high degree of bias. Many studies of nest predation use artificial nests containing fresh quail eggs, which are slightly larger than the eggs of most songbirds. Haskell suggests that small mouthed predators, such as chipmunks and mice, cannot break these larger eggs, resulting in an underestimation of overall nest predation rates where these are the predominant predator species. He also suggests that predation rates by some of these predators increases with increasing size of forest fragment and distance from an edge. He used small artificial eggs made from modelling clay, which enabled him to identify what species of animal was attempting to prey on the eggs. His results show that no significant difference exists between overall predation rates, even though the dominant predator species may change in forest fragments of different sizes. Major and Kendall (1996) also stress that identification of predator species is an important part of interpreting results from nest predation studies. Several other factors are also important to consider when assessing the potential effects of nest predation, including nest location, nest type, visibility of nests and their relative attractiveness to predators (Major and Kendall 1996).

1.3.3 Brood Parasitism:

Brown-headed Cowbirds (*Molothrus ater*) are a species of bird credited for much of the concern over declines of forest songbirds in eastern North America. They are the only obligate brood parasite in North America. An obligate brood parasite is a species that never raises it's own young, but instead, clandestinely lays eggs in the nests of other species of birds, allowing those birds to raise the cowbird young as their own. Historically, the Brown-headed Cowbird was found primarily on the great plains of the continent, closely associated with the *Bison* herds that roamed the countryside, but has increased it's range and abundance more than any other native bird species in North America since European settlement (Rothstein et al. 1986, Kaufman 1996). This is largely due to the opening up of land in the eastern part of the continent, where, so far, most of the cowbird population increases have occurred. Brood parasitism by cowbirds has increased to a large extent in the recent past because of the large increase in open grass and farmland which they can occupy. The subsequent decrease in isolated forest habitat has enabled cowbirds to exploit areas which they otherwise could not (Brittingham and Temple 1983). It appears that cowbirds do not need large gaps between forest fragments in order to move in and utilise the deforested area. Rich et al. (1994) found an increase in cowbird abundance in narrow, grassy rights-of-way as small as 8 meters in width.

Female cowbirds can lay more than 40 eggs in one breeding season, and their eggs mature and hatch very quickly relative to many other birds (Kaufman 1996). Adult females will sometimes remove eggs of the host species from the nest before laying their own, further reducing the productivity of hosts. In many cases, the host species have no evolutionary defense against the cowbird, i.e. removing the cowbird eggs or abandoning the parasitized nest; they simply feed the largest and most aggressive individuals in the nest to the best of their ability, all too often at the expense of their own young. In many cases the cowbird young are even larger than the surrogate parents, and the host young are helpless to compete against them (Kaufman 1996). The endangered Kirtland's Warbler (*Dendroica kirtlandii*) is an example of a species that is highly vulnerable (Mayfield 1977), as well as the Acadian Flycatcher (*Empidonax virescens*), which never raises any of it's own young if it's nest is successfully parasitized (Walkinshaw 1961).

1.3.4 Barriers to Movement/Dispersal:

Gaps in forests may function as barriers to movement for forest bird species, despite their high vagility. Birds may avoid open areas due to an increased risk of predation by avian predators (e.g., Suhonen 1993), and when birds do venture into open areas, survival of individuals may decrease because of predation (Matthyson and Currie 1996). Desrocher and Hannon (1997) found that birds in the post fledging period were less willing to respond to chickadee mobbing calls when it was necessary to cross a gap in the forest. Further, willingness to cross decreased as the width of the gap increased. They also found that, when responding, birds choose to detour around open areas along forest edges, despite increasing the distance they must travel, and therefore, their energy cost. Juvenile dispersal may be particularly important for many songbirds, as they may scout for potential breeding territories in their fledging year (Brewer and Harrison 1975, Matthyson and Currie 1996). Matthyson and Currie (1996) found that dispersal success of juvenile Nuthatches (*Sitta europaea*) was reduced in fragmented habitats. The reduction in movement routes for birds could result in effective separation of populations, and expose isolated groups to dangers associated with small populations. i.e. loss of genetic diversity and stochastic events.

1.4 Forest Birds:

Birds were chosen as the study group for this research for several reasons. Many species of birds in North America, particularly neo-tropical migrants, have been shown to be at least partially dependent on large contiguous tracts of old growth forest (Ambuel and Temple 1983, Morton 1992). Also, birds are the most diverse vertebrate taxa in Alberta and in the boreal forest (Smith 1993). Because of this sensitivity and diversity, birds serve as important indicator species within forest biomes (Morrison 1986). As indicators, forest birds may be used to explore the extent that linear developments are affecting the forest ecosystem as a whole. Finally, birds have a relatively conspicuous nature, and study methods have been well established for this group (e.g., Ralph et al. 1995).

1.5 Fragmentation in the Boreal Forest:

In the boreal forest, there is evidence that some forest nesting birds may be resilient to the effects of forest fragmentation (Schmiegelow et al. 1997). This has also been suggested for birds in some montane forests in British Columbia (Schieck et al. 1995). Explanation for these results lies with the natural disturbance regime, which, in both cases, is medium to large scale disturbance in the form of fire or insect outbreaks, creating a patchwork mosaic of various stand ages and compositions across the landscape. If birds in these areas have evolved in forest types where natural fragmentation is a normal event, they may be well adapted to deal with such situations. It should, however, be noted that both Schmiegelow et al. (1997) and Schieck et al. (1995) state that caution should be used when interpreting these results, because both studies were conducted over a relatively short time period following forest harvest. Schmiegelow et al. (1997) also caution that their study area was embedded in a landscape that contained large areas of undisturbed forest, which may have influenced results of the study. Longer term data for the same study (Schmiegelow and Hannon 1999) show significant downward trends for certain species, such as the Black-throated Green Warbler (*Dendroica virens*) and Black-capped Chickadee (*Poecile atricapillus*). These species are considered at high risk from the effects of forest fragmentation, due to a dependence on old, interior forest habitat. Other species in the area have stable or increasing abundance, showing resilience or even preference for the early seral stages created by forest harvest, and the edges associated with them.

1.6 Linear Developments:

The construction and maintenance of narrow, forest dividing corridors, such as roads, seismic lines, powerlines and pipelines, is commonplace in the forests of Alberta. The oil and gas industry in Alberta creates such disturbances through construction of the infrastructure needed to access petroleum resources. While much of this disturbance is temporary, and vegetation regenerates once work in the area is complete, some of these features are quite permanent. Pipelines and roads, for example, are usually maintained for many years, even decades. Linear features such as these are not generally perceived as having a great impact on the amount of available habitat for forest dwelling species, which may be a misconception. The extent of these linear disturbances in Alberta is vast. For example, as of December 1996, there were over 73,000 km of pipeline RoW alone in the boreal forest region of Alberta, including only collection pipelines, not the distribution network (AEP 1998). Including only the area within the RoW as habitat lost, and using conservative estimates for widths of RoW (15 meters), this amounts to almost 1100 km^2 (AEP 1998). The actual amount of habitat lost for some species due to reduction in interior forest (i.e. away from edges), can potentially be much greater (Reed et al. 1996). The continued increase in the rate of exploration and extraction of resources (Marchak 1995), can only result in an increase of linear disturbances in the future. Linear disturbances such as rights-of-way have been shown to have effects on many wildlife species (Kroodsma 1982a, Rich et al. 1994), including the habitat loss issues mentioned above. In addition, some species of birds may see such gaps in the forest as a barrier to movement (Rail et al. 1997). Due to the linear, unbroken nature of pipeline RoW, this may result in effective division of habitat.

1.7 Project Goals:

In this study, I examined how linear features, specifically pipeline RoW, contribute to overall habitat loss for forest dwelling species by comparing the bird community, and relative abundances of individual species, in forests adjacent to RoW, and control plots in relatively undisturbed forests. In addition, I attempted to measure how the pipelines contribute to one factor, nest predation, that has been implicated in contributing to interior forest habitat loss for some bird species, using an artificial nest experiment. Also, I measured how linear features may be contributing to fragmentation, or isolation, of habitat by collecting some preliminary data on whether they are acting as barriers to movement for bird species.

The study was carried out over two field seasons in the Gold Creek area, in the boreal mixedwood forest south of Grande Prairie, Alberta (Figure 1.1).

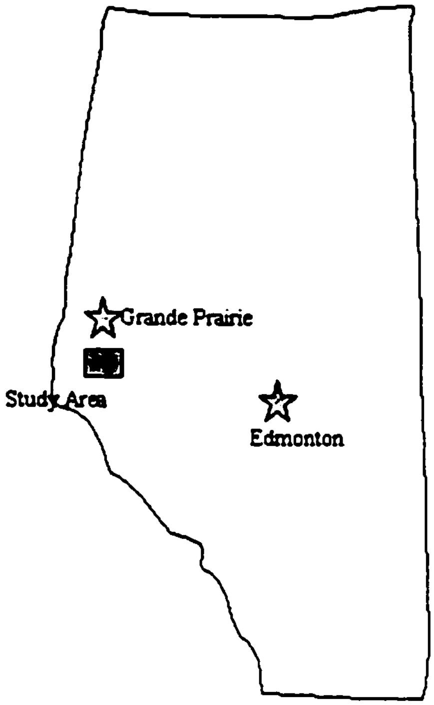


Figure 1.1: Map of Alberta, Canada, showing the study area of about 100 square km., 40 km. south of Grande Prairie in mixedwood boreal forest.

In boreal Alberta, the width of forest-dividing corridors is highly variable. Seismic exploration lines may be as narrow as several meters, while pipeline RoW may be as wide as 90 meters. Traditionally, pipeline construction in areas with an existing RoW would involve 'looping' subsequent lines along the same RoW, resulting in an increase in the width of the corridor. The research proposed here will focus on pipeline RoW of various widths, and their effects on the bird communities in adjacent, forested areas. This work has the following objectives:

1) To determine the effect of RoW width on forest songbird community composition, and individual species abundance, on and adjacent to the RoW (Chapter 2).

2) To measure the relative effect of different widths of RoW on rates of nest depredation at different distances from the edge, and to determine what species of predator are contributing to depredation at these distances from edge (Chapter 3).

3) To determine whether different widths of RoW are acting as barriers to movement of birds across these gaps (Chapter 4).

The focus on various widths of RoW in all objectives will allow for assessment of whether 'looping' of lines results in greater fragmentation and loss of habitat for forest songbird species.

1.8 Literature Cited

Alberta Environmental Protection (AEP) 1998. The Boreal Forest Natural Region of Alberta.

Ambuel, B. and S.A. Temple 1983. Area-dependent changes in the bird communities and vegetation of southern Wisconsin forests. Ecology **64**(5): 1057-1068.

Anderson, S.H., K. Mann and H.H. Shugart jr. 1977. The effect of transmission-line corridors on bird populations. The American Midland Naturalist **97**(1): 216-221.

Bancroft, G.T., A.M. Strong, and M. Carrington 1995. Deforestation and its effects on forest-nesting birds in the Florida Keys. Conservation Biology **9**(4): 835-844.

Bibby, C.J. 1995. Recent past and future extinctions in birds. *In* J.H. Lawton and R.M. May (eds.) Extinction Rates. Oxford University Press, Oxford. Pp. 98-110.

Bissonette, J.A. 1997. Scale sensitive ecological properties: historical context, current meaning. In J.A. Bissonette (ed.) Wildlife and Landscape Ecology. Springer.

Brewer, R. and K.G. Harrison 1975. The time of habitat selection by birds. Ibis **117**: 521-522.

Brittingham, M.C. and S.A.Temple 1983. Have cowbirds caused forest songbirds to decline? Bioscience **33**: 31-35.

Desrochers, A. and S.J. Hannon 1997. Gap crossing decisions by forest songbirds during the post-fledging period. Conservation Biology **11**(5): 1204-1210.

Ehrlich, P.R. 1995. The scale of the human enterprise and biodiversity loss. *In* J.H. Lawton and R.M. May (eds.) Extinction Rates. Oxford University Press, Oxford. Pp. 214-226.

Fahrig, L. 1999. Forest loss and fragmentation: Which has the greater effect on persistence of forest-dwelling animals. *In* J.A. Rochelle, L.A. Lehmann and J. Wisniewski (eds.) Forest Fragmentation: Wildlife and Management Implications. Brill, Leiden, Boston, Koln. Pp. 87-95.

Gates, J.E. and L.W. Gysel 1978. Avian nest dispersion and fledging success in field-forest ecotones. Ecology **59**(5): 871-883.

Groomsbridge, B. (ed.) 1992. Global Biodiversity: State of the Earths Living Resources. Chapman and Hall, New York, NY. 585 pp.

Hagan, J.M., W.M. Vander Haegen and P.S. McKinley 1996. The early development of forest fragmentation effects on birds. Conservation Biology **10**(1): 188-202.

Haskell, D.G. 1995. A reevaluation of the effects of forest fragmentation on rates of bird-nest predation. Conservation Biology **9**(5): 1316-1318.

Kaufman, K. 1996. Lives of North American Birds. Houghton Mifflin Company, Boston, MA. 675p.

Kroodsma, R.L. 1982a. Bird community ecology on power-line corridors in east Tennessee. Biological Conservation **23**: 79-94.

Kroodsma, R.L. 1982b. Edge effect on breeding forest birds along a power-line corridor. Journal of Applied Ecology **19**: 361-370.

Levins, R. 1970. Extinction. *In* M. Gerstenhaber (ed.) Some Mathematical Problems in Biology. American Mathematical Society, Providence, RI. Pp. 75-107.

MacArthur, R.H. and E.O. Wilson 1967. The Theory of Island Biogeography. Princeton University Press, Princeton, NJ.

Major, R.E. and C.E. Kendal 1996. The contribution of artificial nest experiments to understanding avian reproductive success: a review of methods and conclusions. Ibis **138**: 298-307.

Marchak, M.P. 1995. Logging the Globe. McGill-Queen's University Press. Montreal and Kingston, PQ and ON. 404 p.

Matthyson, E. and D. Currie 1996. Habitat fragmentation reduces disperser success in juvenile nuthatches *Sitta europaea*: evidence from patterns of territory establishment. Ecography **19**: 67-72.

Mayfield, H.F. 1977. Brown-headed cowbird: agent of extermination? American Birds **31**: 107-113.

McComb, W.C. 1999. Forest fragmentation: wildlife and management implications, synthesis. *In* J.A. Rochelle, L.A. Lehmann and J. Wisniewski (eds.) Forest Fragmentation: Wildlife and Management Implications. Brill, Leiden, Boston, Koln. Pp. 295-301.

Morrison, M.L. 1986. Bird populations as indicators of environmental change. *In* Johnston, R.F. (ed.) Current Ornithology, volume 3. Plenum Press, New York, NY. Pp. 429-451.

Morton, E.S. 1992. What do we know about the future of migrant landbirds? *In* J.M. Hagen and D.W. Johnston (eds.) Ecology and Conservation of Neotropical Migrant Landbirds. Smithsonian Institution Press.

Odum, E.P. 1971. Fundamentals of Ecology. 3rd Edition. W.B. Saunders Company. Philadelphia, PN.

Potvin, F. and L. Breton 1997. Short-term effects of clearcutting on martens and their prey in the boreal forest of western Quebec. *In* G. Proulx, H.N. Bryant and P.M. Woodard (eds.) *Martes*: Taxonomy, Ecology, Techniques, and Management. Provincial Museum of Alberta, Edmonton AB. Pp. 452-474.

Rail, J.F., M. Darveau, A. Desrochers and J. Huot 1997. Territorial responses of boreal forest birds to habitat gaps. The Condor **99**: 976-980.

Ralph, C.J., J.R. Sauer and S. Droege, technical editors 1995. Monitoring Bird Populations by Point Counts. Gen. Tech. Rep. PSW-GTR-149. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 187p.

Reed, R.A., J. Johnson-Bernard and W.L. Baker 1996. Contribution of roads to forest fragmentation in the Rocky Mountains. Conservation Biology **10**(4): 1098-1106.

Rich, A.C., D.S. Dobkin, and L.J. Lawrence 1994. Defining forest fragmentation by corridor width: the influence of narrow forest-dividing corridors on forest-nesting birds in southern New Jersey. Conservation Biology **8**(4): 1109-1121.

Rothstein, S.I., D.A. Yokel and R.C. Fleischer 1986. Social dominance, mating and spacing systems, female fecundity, and vocal dialects in captive and free-ranging brown-headed cowbirds. *In* Johnston, R.F. (ed.) Current Ornithology, volume 3. Plenum Press, New York, NY. Pp. 127-185.

Schieck, J., K. Lertzman, B. Nyberg and R. Page 1995. Effects of patch size on birds in old-growth montane forests. Conservation Biology **9**(5): 1072-1084.

Schmiegelow, F.K.A. and S.J. Hannon 1993. Adaptive management, adaptive science and the effects of forest fragmentation on boreal birds in northern Alberta. Transactions 58th North American Wildlife and Natural Resources Conference: 584-598.

Schmiegelow, F.K.A. and S.J. Hannon 1999. Forest-level effects of management on boreal songbirds: the Calling Lake fragmentation studies. *In* J.A. Rochelle, L.A. Lehmann and J. Wisniewski (eds.) Forest Fragmentation: Wildlife and Management Implications. Brill, Leiden, Boston, Koln. Pp. 201-221.

Schmiegelow, F.K.A., C.S. Machtans and S.J.Hannon 1997. Are boreal birds resilient to forest fragmentation? An experimental study of short-term community responses. Ecology **78**(6): 1914-1932.

Smith, A. 1993. Ecological profiles of birds in the boreal forest of western Canada. *In* D.H. Kuhnke (ed.) Birds in the Boreal Forest: Proceedings of a Workshop Held March 10-12, 1992 in Prince Albert, Saskatchewan. Northern Forestry Centre, For. Can., NW Region. Edmonton, AB. pp 14-26.

Suhonen, J. 1993. Predation risk influences the use of foraging sites by tits. Ecology **74**: 1197-1203.

Thomas, J.A. and M.G. Morris 1995. Rates and patterns of extinction among British invertebrates. *In* J.H. Lawton and R.M. May (eds.) Extinction Rates. Oxford University Press, Oxford. Pp. 111-130.

Walkinshaw, L.H., 1961. The effect of parasitism by the brown-headed cowbird on *Empidonax* flycatchers in Michigan. Auk **78**: 266-268.

Wilcove, D.S.,1985. Nest predation in forest tracts and the decline of migratory songbirds. Ecology **66**(4): 1211-1214.

Chapter 2: Bird Community Responses to Pipeline Rights-of-Way in Boreal Alberta

2.1 Introduction:

2.1.1 Boreal Forest:

The boreal forest of Canada is a massive ecosystem, covering about 28% of the land mass of North America north of Mexico, and making up more than 60% of the forested area of Canada and Alaska. It is mostly comprised of a few species of trees: white spruce (*Picea glauca*), black spruce (*Picea mariana*), trembling aspen (*Populus tremuloides*), balsam poplar (*Populus balsamifera*) and paper birch (*Betula papyrifera*). These trees occur in pure and mixed stands, depending mostly on moisture conditions and seral stage (age) of the forest. The dominant disturbance regimes found in the boreal are medium to large scale, from fire and insect outbreak, and result in a variety of age and composition classes, distributed in a complex mosaic across the landscape. Until recently, there was little economic value for the deciduous tree species found in the boreal forest, and most of the logging that occurred there was focused on mature stands of white spruce, which were used for saw logs. This changed drastically in the past decade, with new found value of aspen and poplar trees for pulp production (Schmiegelow and Hannon 1993, Marchak 1995).

The expanding human population, global economic growth and improved technology for resource extraction are placing more pressure on forest ecosystems everywhere. Issues of forest fragmentation and removal of forest habitat from human development and resource extraction are prevalent throughout the world. In Alberta, during the past decade, the boreal forest ecotypes, which make up over half of the entire province (Achuff 1994), have become increasingly utilized as sources of pulp (Marchak 1995), and oil and gas exploration and development in the area has continued to expand.

Most of the research in North America on fragmentation effects on songbirds has been conducted in the eastern deciduous forests of the continent, and usually in landscapes that are dominated by agriculture practices. There may be limited applicability of much of this research to the boreal forest, as the region bears little resemblance to such habitats in terms of the disturbance types, overall landscape composition, and the animal species native to the area (e.g., Tewksbury et al. 1998). There is a need and an opportunity to conduct research on anthropogenic disturbances in the boreal forest, in order to better understand their effects on wildlife species, and make better management decisions to help conserve boreal forest ecosystems.

2.1.2 Forest Loss vs. Fragmentation:

The issues associated with forest habitat loss and forest fragmentation are inseparable, and yet there is an important distinction between them (Fahrig 1999). Forest fragmentation occurs when an area of forest is split into two or more pieces by a disturbance event. The disturbance event can be either natural, such as fire, or human caused, such as logging, but will always involve removal of some forest area, and therefore loss of forest habitat. Habitat loss from anthropogenic disturbance is likely the most important cause of decline for threatened species in forests all over the world (Fahrig 1999).

The effective habitat loss from disturbance (i.e. removal of forest) can be much greater than the actual area of forest loss, due to fragmentation effects such as those associated with edges. Edge effects are conditions associated with the forest edge that change both biotic and abiotic factors associated with the area, such as vegetation, micro-climatic conditions and wildlife species presence and abundance. These changes may affect the suitability of areas for many forest dwelling species (Kremsater and Bunnell 1999). For example, an increase in abundance of birds associated with open areas or younger ages of forest may result in increased competition for forest species attempting to nest in old forests near edges. As a result, the forest species may avoid the area altogether, or may be less productive. Reductions in productivity may create a population sink, or ecological trap (e.g., Gates and Gysel 1978). The large amount of industrial activity now present in the boreal forest may be creating situations for some species that will result in long term population declines, or even local extinction.

Logging is the main industrial activity associated with loss of old forest habitat, however, the contribution of oil and gas activities to forest loss and fragmentation is immense (AEP 1998). Oil and gas companies remove forest to gain access to, and transport out, petroleum resources. They create wellsites, roads, seismic lines and pipelines, many of which are relatively permanent features on the landscape. In particular, linear features like roads and pipelines are usually planted with commercial grass seed mixes, and then managed in perpetuity in order to prevent vegetation encroachment. In the boreal forest natural region of Alberta, as of December, 1996, there were over 73,000 km of pipeline RoW in place (AEP 1998), which is an incomplete inventory. Associated forest loss, excluding edge effects, is estimated at about 1100 km^2

(AEP 1998), which again, is a conservative estimate. Cumulative effects of this type of development, coupled with forestry activities, represents extensive loss and alteration of forest habitat.

The objective of this study was to determine how linear developments, specifically pipeline RoW, contributed to habitat loss for forest dwelling bird species. I used different widths of RoW as treatments, and examined the bird communities in forests adjacent to them, and at control sites removed from any major human disturbance, to evaluate community and individual species response to the presence of RoW.

I predicted the following: 1) some species of birds, particularly those associated with interior forests, would be less abundant near RoW edges due to edge avoidance or displacement by open area and edge species; 2) some species of birds would occur at or near the RoW edges almost exclusively; and 3) both species richness and the overall abundance of birds would be higher in the forests adjacent to the RoW than in interior forests, due to the addition of species associated with open areas and edges, and the continued presence of many species of forest associated birds.

2.2 Methods:

2.2.1 Study Site:

The dry mixed-wood and/or central mixed-wood sub-regions of the boreal forest were chosen for the study due to their relatively large area within Alberta, and because both are likely to be subjected to large amounts of oil and gas development in the near future. Potential areas for the project were located using phase 3 forest cover maps and resource access maps obtained from Alberta Environmental Protection, and in consultation with TransCanada Pipelines (TCP), a partner in the research. Field visits were conducted early in 1998 to determine the feasibility of each of several potential areas. Final site selection was based on the availability of RoW of varying widths within a logistically feasible area. The area selected was Gold Creek, approximately 40 km south of Grande Prairie, Alberta (Figure 1.1, Chapter 1).

The forest in the study area was dominated by trembling aspen, with patches containing varying amounts of white spruce, black spruce in poorly drained areas, and balsam poplar. White birch was also found throughout the area. The understory contained saplings of the forementioned tree species, as well as many shrub species, including alder (*Alnus spp.*), beaked hazelnut (*Corylus cornuta*), willow (*Salix spp.*), honeysuckle (*Lonicera spp.*), low-bush cranberry (*Vibernum edule*), prickly rose (*Rosa acicularis*), gooseberry (*Ribes spp.*) and raspberry (*Rubus idaeus*). The herbaceous plants included asters (*Aster spp.)*, goldenrods (*Solidago spp.*), bedstraws (*Galium spp.*) and bunchberry (*Cornus canadensis*). The forest floor was typically covered with leaf litter, due to the predominance of deciduous trees. All forests sampled in this study were between 80 and 110 years of age, determined from origin dates on Alberta phase III forest cover maps.

The RoW selected for the study sites were well established, i.e. more than 5 years old, with similar internal vegetation structure. Shrubs and tree saplings growing within the RoW were less than 3 meters in height and sparsely distributed. Grass and sedges made up a majority of the ground cover.

2.2.2 Study Design:

Consideration was given to RoW that were of widths commonly found in the area of study, and that conformed to typical RoW widths as constructed by TCP. TCP RoW containing a single pipeline range in width from 16 to 32 meters, depending on the size of pipe used. When more than one pipe is contained within one RoW, a practice called 'looping', these widths can be much greater. Three replicate sites were found and surveyed in each of four width classes: 15-16 meters, 22-24 meters, 32-34 meters and greater than 50 meters, for a total of 12 sites.

Vegetation Data:

Vegetation data were collected at all sites. Vegetation transects (3 in total, per site) ran through the point count stations, perpendicular to the RoW (see below). Eight plots were located on each transect: one in the RoW, at 25, 50, 75, 100, 150 and 200 m from the edge of the RoW, and at control locations 500 meters from the edge. Partial plots (excluding the large circle, see below) were sampled immediately adjacent to the edge (0- 10 meters from edge). Hence, there were 24 full plots per site, and 3 partial plots at 0-10 meters from edge. At each location, circular plots of 0.04 ha (11.3 meter radius) were sampled, with an internal circle of 0.008 ha. (5 meter radius) demarcated. Four, 1m square quadrats were placed within the plot, at 5 meters from the center, in each of the four cardinal directions. All trees and snags (standing, > 8 cm. dbh) were counted within the large circle, and all saplings, poles (< 8 cm. dbh, > 2 meters high) and shrubs (< 2 meters high) were counted within the small circle. In each of the four quadrats, estimates to the nearest 5% were taken for cover of green material, live grass/sedges, shrubs < 50 cm high, forbs, woody debris, moss, ferns and leaf litter.

Bird Community:

In the first field season (1998), point counts were used to collect bird data. Point counts enable measurement of the relative abundance of bird species in different locations, by enumerating all birds heard or seen within a fixed area over a fixed period of time (see Ralph et al. 1995).

Each site contained a grid of 6 point counts: three in the adjacent forest at a distance of 100 meters from the edge, and three at a minimum distance of 500 meters from the edge, which served as controls (Figure 2.1). Point counts sampled a 100 meter radius and were 5 minutes in duration. Each site was visited three times between May 27 and July 7, 1998. All counts were conducted between sunrise and 10:00 a.m., and only in conditions of little or no rain and winds less than Beaufort level 5.

In the second field season (1999), bird community data were collected using a series of line transects in addition to the point counts (Figure 2.2). Transects ran parallel to the RoW, and birds within 50 meters on either side of the transect were recorded and mapped. This sampling technique conformed more closely to the edge of the RoW, enabling more complete coverage of the forest adjacent to the RoW than the point count stations (Morneau et al. 1999). Transects 600 meters in length were located 50 and 150meters from the edge of each RoW. Matching control transects were placed at distances of 450 and 550 meters from the edge. Each site was sampled twice in 1999, between dawn and 10:00 a.m., in favourable weather conditions.

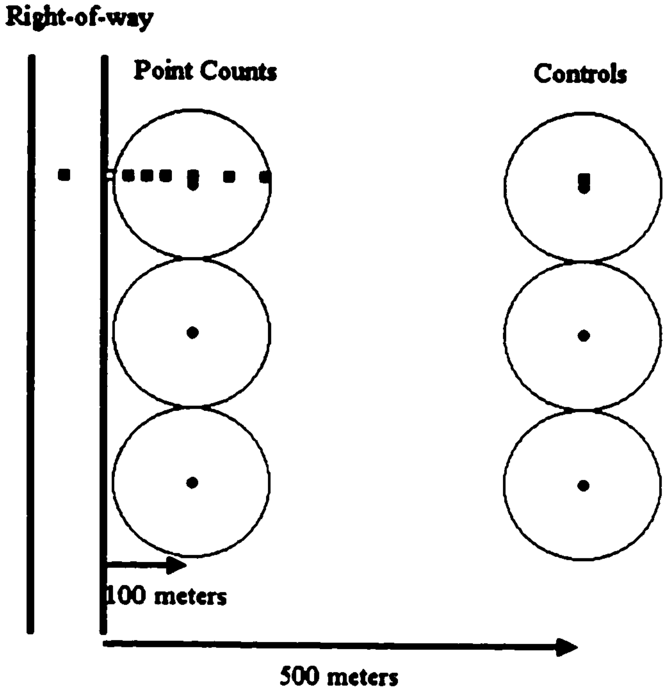


Figure 2.1: Configuration of point count stations (small circles) in relation to RoW (dark lines), and point count areas (large circles), for bird community sampling in boreal forest south of Grande Prairie, Alberta, 1998/99. Vegetation plot locations in relation to RoW edge are dark rectangles. Partial vegetation plots are hollow rectangles. Vegetation plots are located in three transects; one associated with each point count station.

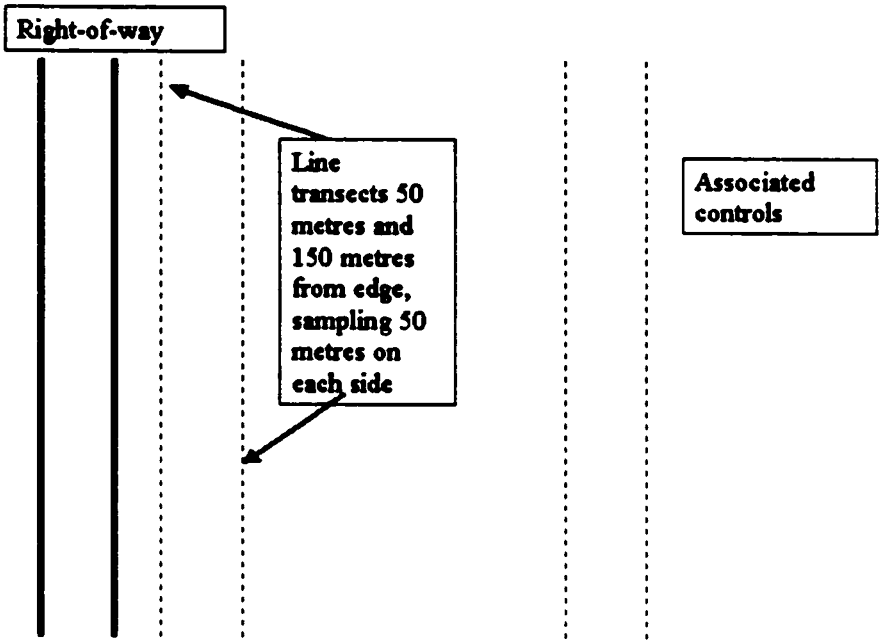


Figure 2.2: Location of line transects (dotted lines) in relation to RoW edges (heavy lines) for bird community sampling in boreal forest south of Grande Prairie, Alberta, 1999.

2.2.3 Data Analysis:

All data were tested for normality prior to analysis, and non-parametric tests were used where appropriate. I used α of 0.05 for the vegetation data because of the large sample sizes, and α of 0.10 for the bird data in order to reduce the possibility of committing type II errors (e.g., Schmiegelow et al. 1997). Statistical analysis was performed with SPSS, version 10.0 (SPSS Inc. 2000).

Vegetation:

Subsets of the vegetation data considered important for nesting birds were selected.. Deciduous trees with dbh > 8 cm were combined for analyses. Saplings and poles (dbh < 8 cm and height > 2 meters) of each species were analysed using stem counts. Percent cover data was analysed for all green vegetation, grass, leaf litter, shrub cover < 50 cm. in height and forbs. All percent cover data were transformed using an arcsine $\sqrt{p}$, after converting percentages to proportions, to account for the unit sum constraint associated with proportional data (Aeibischer et al. 1993). Stem counts of shrubs < 2 meters in height of all species were combined into one variable.

Analysis was first performed with all variables comparing each distance from edge to the control sites using t-tests. Subsequently, tests were run comparing width classes of RoW using one-way ANOVA, for only those distances from edge that showed significant differences from controls.

Bird Community:

Most passerine species, and the Yellow-bellied Sapsucker (*Sphyrapicus various*) were included in analyses, but all corvids, raptors, grouse, waterbirds, and other woodpeckers were excluded, as these species are not adequately sampled using point counts.

Measurements of species richness were calculated using the total number of species detected, over all visits in each year, at adjacent (100 meters from edge) and interior (500 meters from edge) point count locations, for each site. Measurements of abundance represent the mean number of bird detections at each site, at each type of point count location (adjacent or control), over all visits in each year. I first tested for year effects using paired samples t-tests. Differences in measures of richness and abundance between adjacent and interior locations were subsequently analysed separately for each year of the study. Non-parametric Wilcoxon signed ranks tests were used due to non-normal distributions. I tested for differences between width classes of RoW, in each year of the study, including only the measures from adjacent point counts, using non-parametric Kruskal-Wallis ANOVA. Differences in the abundance for individual species with 10 or more detections were tested using the same methods.

Similar analyses were conducted for the line transect data collected in 1999, however the data were separated into 100 meter intervals for distance from RoW edge. Species richness and abundance measurements from each site, at each of four distances from edge: (1) 0-100 meters, (2) 100-200 meters, (3) 400-500 meters and (4) 500-600 meters, were derived as for the point count data. Distances 1 and 3 were paired, as were distances 2 and 4, and Wilcoxon tests were used to examine differences. Kruskal-Wallis ANOVA was used to test for differences between the four width classes of RoW, using only data from distances 1 and 2, which were analysed separately. Similar analyses were completed for individual species with more than 10 detections.

2.3 Results:

2.3.1 Vegetation

Comparison of each distance from edge to control sites indicated that significant differences existed in percent cover data and shrub counts only for the plots within RoW, and those 10 meters from the edge. All green cover and grass cover were higher in RoW plots than at controls ($t = 3.9$ and 14; $p = 0.001$ and < 0.001 respectively). Cover of leaf litter, shrubs and forbs, and shrub stem counts were all higher in control plots than in RoW plots ($t = -21, -10, -2.5$ and -5.8; $p = < 0.001, <0.001, 0.022$ and < 0.001 respectively; Table 2.1). Percent cover of forbs was higher in the edge plots (0-10 meters) than at control plots ($t = 2.9$; $p = 0.008$). Percent cover of leaf litter and shrub stem counts were higher at the control plots than at the edge plots ($t = -4.0$ and -3.6; $p = 0.001$ and 0.002 respectively; Table 2.1). At distances 25 meters or more from edge, percent cover and shrub count variables showed no significant differences from controls.

Significant results for the within RoW plots between width classes include percent cover of grass and shrub, with grass cover higher in the wider width classes ($F = 6.4$; $p = 0.016$) and shrub cover higher in the narrower widths ($F = 4.5$; $p = 0.039$) (Table 2.2). Vegetation attributes within the 10 meter plots had no significant differences between width classes.

Trees and saplings were not present in the RoW plots, and trees were not counted in the partial plots at 10 meters from edge. There were no significant differences in tree counts for any other distance from edge when compared to controls, however, there were differences in sapling counts up to 50 meters into the forest. Willow saplings were more abundant at 10 meter, 25 meter and 50 meter plots when compared to controls. Poplar saplings were more abundant at 10 and 25 meter plots, and Alder saplings were more abundant at 10 meter plots (Table 2.1). There were no differences in sapling counts for any of these distances from edge when compared between width classes, but Poplar saplings were marginally more abundant in the 10 meter plots adjacent to the widest width class of RoW ($p=0.056$).

Table 2.1: Results of vegetation analysis for boreal forest south of Grande Prairie, Alberta, 1998/99. Comparison of RoW plots and various distances from edge to control plots using paired t-tests. Only significant results are shown. (N = 24, df =22 for all comparisons).

Variable	Sample Mean	Control Mean	t	P
RoW Plots				
Shrubs (#)	8.9	28	-5.8	<0.001
Percent Cover				
All green	90	81	4.0	0.001
Grass	70	6.6	14	<0.001
Leaf Litter	11	90	-21	<0.001
Shrubs	15	57	-10	<0.001
Forbs	18	28	-2.5	0.022
0-10 meter Plots				
Shrubs (#)	18	28	-3.6	0.002
Percent Cover				
Leaf Litter	70	90	-4.0	0.001
Forbs	41	28	2.9	0.008
Saplings (#< 8cm.)				
Poplar	2.1	0.4	3.3	0.004
Willow	4.5	0.3	3.0	0.007
Alder	3.0	0.8	2.4	0.027
25 meter Plots				
Saplings (#< 8cm.)				
Poplar	1.3	0.4	2.2	0.037
Willow	2.1	0.3	2.3	0.029
50 meter Plots				
Saplings (#< 8cm.)				
Willow	1.6	0.3	2.2	0.038

Table 2.2: Results of vegetation analysis for boreal forest south of Grande Prairie, Alberta, 1998/99. Vegetation comparisons between 4 width classes of RoW: width 1 (15-16 meters), width 2 (22-24 meters), width 3 (32-34 meters) and width 4 (>50 meters). Comparisons performed individually for within RoW plots and all distances from edge. Only significant results are shown. (N = 12 (n = 3 per width class), total df = 11).

Variable	Width 1	Width 2	Width 3	Width 4	t	P
Within RoW plots						
Percent cover						
Grass	61	59	79	84	6.4	0.001
Shrub	23	18	18	0.2	4.5	<.001

2.3.2 Bird Community

Point Count Data:

Tests for differences between years indicated that species richness did not change ($p = 0.724$), but abundance measures were higher in 1999 than in 1998 ($p < 0.001$). All subsequent tests were then run separately for each year. In 1998, neither the number of species ($p = 0.937$), nor total abundance of birds ($p = 0.969$), differed between sampling areas adjacent to pipeline RoW and control areas ($n = 12$ in both cases). There was also no significant difference between the four width classes of RoW in the number of species detected adjacent to the RoW ($p = 0.977$, $n = 3$ for each width class), nor in the abundance of birds ($p = 0.187$, $n = 3$ for each width class). In 1999, abundance measures between adjacent and control counts were also similar ($n = 12$, $p = 0.261$), as were measures of species richness ($n = 12$, $p = 0.119$). Abundance measures at adjacent counts were not different among width classes of RoW (p = 0.258, n = 3 for each width class), however, species richness was significantly different among widths (p = 0.076, n = 3 for each width class) (Figure 2.3). The differences in richness among widths showed no pattern consistent with increasing or decreasing width of RoW.

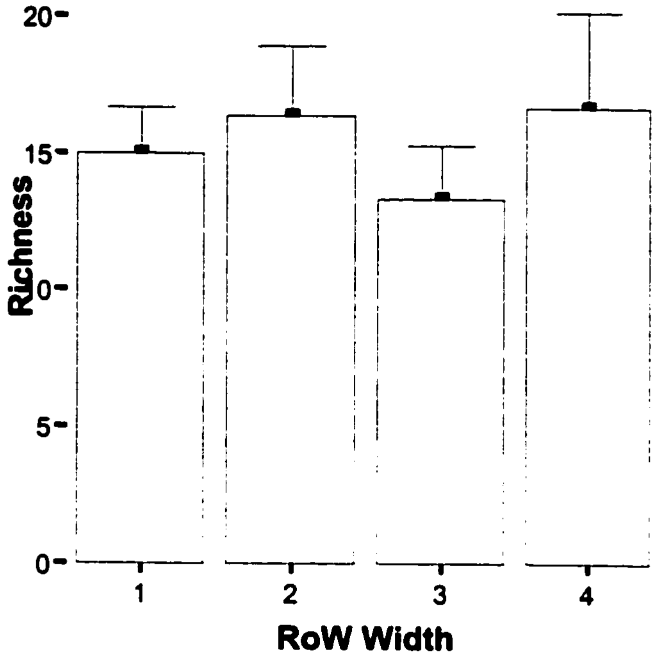


Figure 2.3: Species richness of birds adjacent to RoW of different widths south of Grande Prairie, Alberta, 1999. Data collected using point counts. Width classes are: 1) 15-16 meters, 2) 22-24 meters, 3) 32-34 meters and 4) >50 meters. (n=3 for each width class, p=0.076). Error bars represent 90 % confidence intervals.

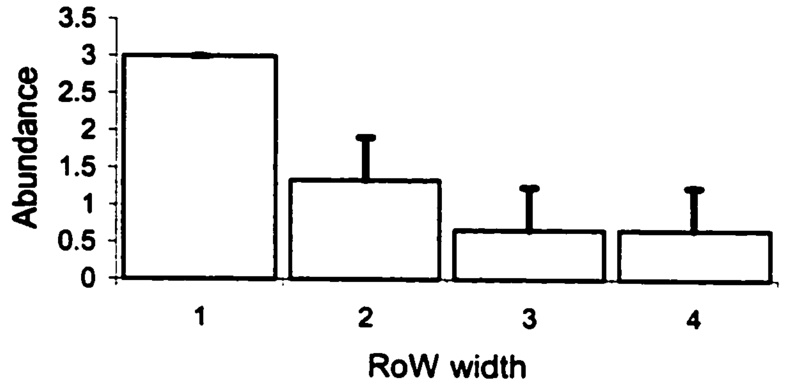
Data on individual species abundance were pooled for both years. Individual species analysis showed seven species that differed in abundance between control and adjacent locations. Five species were more abundant at adjacent locations, including the

Black-capped Chickadee (*Poecile atricapillus*), Least Flycatcher (*Empidonax minimus*), Lincoln's Sparrow (*Melospiza lincolnii*), Magnolia Warbler (*Dendroica magnolia*) and Red-eyed Vireo (*Vireo olivaceus*). Only two species were more abundant at the control stations: Golden-crowned Kinglet (*Regulus satrapa*) and Mourning Warbler (*Oporornis philadelphia*) (Table 2.3). When only adjacent point count stations were used to compare between width classes of RoW, only the Black-capped Chickadee and the Yellow Warbler (*Dendroica petechia*) showed significant differences, with the Chickadee more abundant at the narrowest widths, and the Warbler more abundant at intermediate widths (Figure 2.4).

Table 2.3: Mean number of detections at point counts adjacent to pipeline RoW vs. control point counts for seven bird species in boreal forest south of Grande Prairie Alberta in 1998 and 1999. Only significant results shown.

Species	Mean number of detections		Z	P
	adjacent	control		
Black-capped Chickadee (*Poecile atricapillus*)	1.4	0.83	-1.7	0.084
Golden-crowned Kinglet (*Regulus satrapa*)	1.0	1.6	-1.8	0.066
Least Flycatcher (*Empidonax minimus*)	6.8	4.0	-1.9	0.052
Lincoln's Sparrow (*Melospiza lincolnii*)	0.58	0.17	-1.7	0.096
Magnolia Warbler (*Dendroica magnolia*)	0.83	0.08	-2.1	0.039
Mourning Warbler (*Oporornis philadelphia*)	0.58	1.3	-1.9	0.058
Red-eyed Vireo (*Vireo olivaceus*)	6.5	4.4	-2.0	0.048

a) Black-capped Chickadee



b) Yellow Warbler

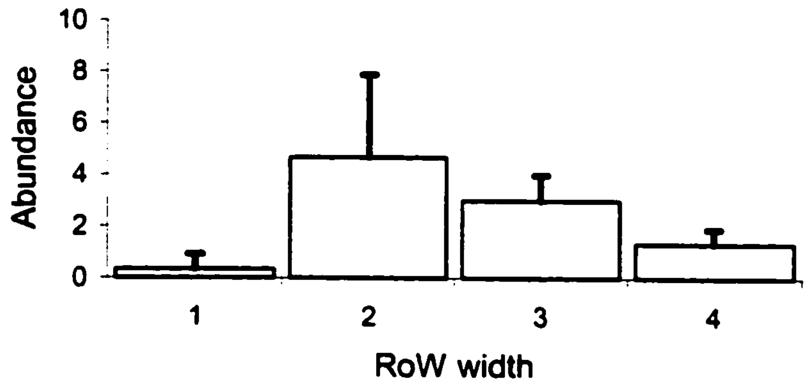


Figure 2.4: Mean number of records of a) Black-capped Chickadee ($\chi^2 = 8.4$, $p = 0.039$), and b) Yellow Warbler ($\chi^2 = 7.1$, $p = 0.068$) from point counts adjacent (100 meters from edge) to RoW of four different widths; 1) 15-16 meters, 2) 22-24 meters, 3) 32-34 meters and 4) >50 meters, in boreal forest, south of Grande Prairie, Alberta. Error bars represent 90 % confidence intervals.

Line Transect Data:

Analysis of the line transect data from 1999 showed no differences in species richness between the areas near the RoW, and the control areas. Distance 1 (0-100 meters from edge) was no different from distance 3 (400-500 meters from edge) ($p = 0.239$), and distance 2 (100-200 meters from edge) was no different from distance 4 (500-600 meters from edge) ($p = 0.754$). However, the abundance of all bird species was significantly higher near the RoW (distance 1 > 3, ($p = 0.012$, $n = 12$), and distance 2 > 4 ($p = 0.020$, $n = 12$)) in contrast to the results from data collected in the same areas using circular point counts (Figure 2.5).

Individual species analysis resulted in 9 species with significantly different detection rates between distances from edge. Seven of these were more abundant near the edges; Least Flycatcher, Lincoln's Sparrow, Purple Finch (*Carpodacus purpureus*), Red-eyed Vireo, Tennessee Warbler (*Vermivora peregrina*), Western Tanager (*Piranga ludoviciana*) and Yellow Warbler. Of these species, all were more abundant at distance 1 (0-100 meters) than distance 3 (400-500 meters), with the exception of the Yellow Warbler, which was more abundant at distances 1 and 2 (100-200 meters) when compared to controls, and the Purple Finch, which was only more abundant at distance 2 when compared to distance 4 (500-600 meters). Two species were more abundant at distance 3 when compared to distance 1; Black-capped Chickadee and Blue-headed Vireo (*Vireo solitarius*) (Table 2.4).

Neither species richness nor abundance were significantly different between width classes of RoW when only data from distance 1 was used. The only individual species that showed a difference between width classes of RoW (at distance 1) was the Ovenbird (*Seiurus aurocapillus*), which was most abundant adjacent to the narrowest RoW class (1), followed by width classes 4, 2 and 3 respectively ($\chi^2 = 6.906$, $p = 0.075$).

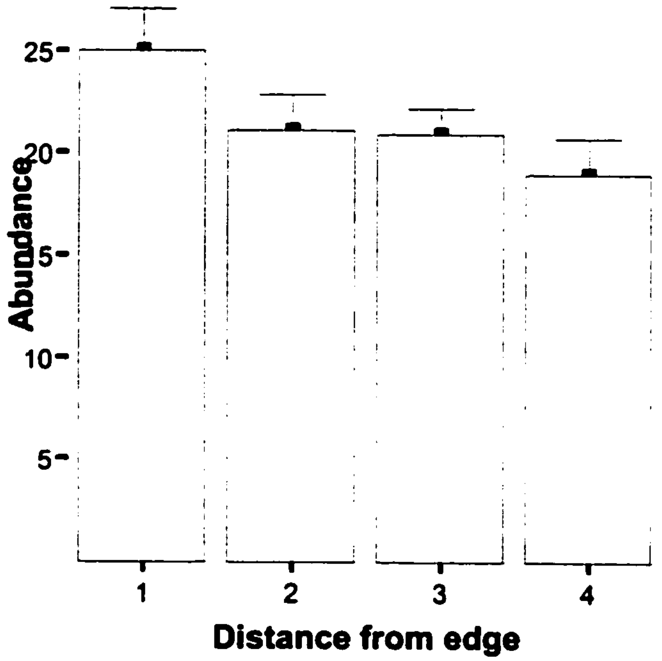


Figure 2.5: Mean abundance of all breeding bird species at various distances into the forest from RoW edge, using line transects in forests south of Grande Prairie, Alberta, 1999. Distances from edge are: 1) 0-100 meters, 2) 100-200 meters, 3) 400-500 meters and 4) 500-600 meters. Paired tests; distances 3 and 4 are controls for distances 1 and 2 respectively (p = 0.012 and 0.020 respectively).

Table 2.4: Mean number of detections on line transects for nine species of birds at 0-100 meters from edge (1), and 100-200 meters from edge (2) of pipeline RoW south of Grande Prairie, Alberta, compared to corresponding control areas in 1999. Only significant results shown.

Species	Mean number of detections		Z	P
	Adjacent (distance)	Paired control		
Black-capped Chickadee (*Poecile atricapillus*)	0.58 (1)	1.5	-1.7	0.082
Blue-headed Vireo (*Vireo solitarius*)	0.67 (1)	1.3	-1.7	0.083
Least Flycatcher (*Empidonax minimus*)	4.2 (1)	2.7	-2.0	0.046
Lincoln's Sparrow (*Melospiza lincolnii*)	1.2 (1)	0.33	-1.7	0.088
Purple Finch (*Carpodacus purpureus*)	0.42 (2)	0.08	-2.0	0.046
Red-eyed Vireo (*Vireo olivaceus*)	2.7 (1)	1.7	-2.1	0.039
Tennessee Warbler (*Vermivora peregrina*)	1.7 (1)	0.50	-1.9	0.058
Western Tanager (*Piranga ludoviciana*)	0.83 (1)	0.33	-1.7	0.084
Yellow Warbler (*Dendroica petechia*)	2.4 (1)	0.83	-2.6	0.011
Yellow Warbler (*Dendroica petechia*)	1.2 (2)	0.42	-1.9	0.058

2.4 Discussion:

The purpose of this study was to determine if RoW of different widths are affecting the bird community in adjacent forests in different ways with respect to effective habitat loss. I predicted that some species of birds would be less abundant near edges, due to preference for contiguous forest areas, and that other species would be present almost exclusively at or near RoW edges. I also predicted higher bird abundance and species richness near RoW edges due to the ecotone between the two habitat types.

Predictions regarding bird species richness were not supported. Richness was not different near RoW edges compared to interior forests, as measured by point counts or line transect data, a result consistent with the findings of other studies (Small and Hunter 1989, Morneau et al. 1999). Overall abundance of birds, however, was higher at edges, based on the line transect data from 1999. The point count data did not show this effect, possibly a result of the circular nature of the point counts, which samples the area immediately adjacent to the RoW less intensively (see Figure 2.1). The width of RoW did not have an effect on bird abundance or species richness in adjacent forests based on either the point count data in 1998, or the line transect data in 1999, but species richness was different between width classes based on point count data from 1999. The results do not, however, indicate a pattern consistent with increasing or decreasing RoW width.

Individual species analysis indicated that the structure of the bird community was somewhat different in forests adjacent to RoW, even if overall richness and bird abundance were not affected greatly. Both the point count data and the line transect data indicated that abundance of some species could be higher or lower in forests close to edges (see Table 2.3 and 2.4). Although these results differed somewhat between the two sampling methods, some species showed consistent patterns, including Least Flycatcher, Lincoln's Sparrow and Red-eyed Vireo, which were more abundant near edges using both methods. Lincoln's Sparrow, in particular, is a species closely associated with open, grassy areas throughout the boreal forest (personal observation). The greater abundance of this species near RoW edges is consistent with the vegetation analysis, in that RoW and areas adjacent to them had elevated grass cover. Species more abundant in interior forest numbered only four using both methods; Black-capped Chickadee, Blue-headed Vireo, Golden-crowned Kinglet and Mourning Warbler. Results for the Black-capped Chickadee were inconsistent between the two methods, having higher abundance near edges using point counts, and higher abundance at controls using line transects. Many species of birds typically associated with interior forest (e.g., Brown Creeper, Canada Warbler and others) were very rare in the study area, and were, therefore, excluded from the individual species analysis.

Understanding how bird communities respond to human induced edges and disturbances is an issue of importance in all forested landscapes, due to the prevalence of human activity. This is especially true for birds that are naturally rare, or that depend on large tracts of contiguous forest for breeding habitat. The creation of gaps in forest cover is implicit in many forms of industrial development. It is important to consider how these gaps are configured on the landscape in order to conserve as much productive habitat as possible. In some systems, large, undisturbed tracts of forest may be the only solution for conserving natural levels of biodiversity. However, in the boreal forest, where large to moderate scale disturbances have created a natural, complex mosaic of forest ages and species composition (Johnson 1992), species may be somewhat more resilient to human caused disturbance (e.g., Schmiegelow et al. 1997) if it is properly planned and implemented.

Developments of some kinds, such as major roads and pipeline RoW, differ from other human disturbances, and from natural disturbances, in one very important way: major roads and pipelines are not allowed to regenerate after harvest, as cutblocks and wellsites generally are, thus making them relatively permanent features on the landscape. They are maintained in a state of relatively short vegetation, and usually with grass as the predominant ground cover. Because of this, the loss of forest habitat is permanent, and novel species that are generally found in grassland type habitat may colonise these areas.

My study examined how linear disturbances of different widths are affecting bird populations and community composition in adjacent boreal forests. I found that RoW of all widths are changing the abundance of some species of birds in adjacent forests. In some cases, abundance is increasing, while in others it is decreasing, but in both cases, the RoW is having an effect on the structure of the bird community. Increases in one species may contribute to decreases in another, due to limitations in resources such as food and nesting habitat. Certain species of birds, such as Lincoln's Sparrow, are quite rare in interior forest habitat, but were found to be relatively common in edge areas adjacent to pipeline RoW. Long term implications of such changes in habitat suitability for specific bird species may result in the loss of some species from forests where permanent, anthropogenic edges are prevalent.

It is important to note that patterns of abundance found during this study may not be consistent with patterns found in other studies in the boreal forest. One potential reason for this is that the forests sampled in this study are not isolated fragments, as were those included in other studies of bird community structure (e.g., Schmiegelow et al. 1997, Schmiegelow and Hannon 1999). The edges created by pipeline RoW may not deter forest interior bird species from approaching, and breeding near them. However, future studies must consider whether these edges are affecting breeding success, in order to determine whether the edges are creating ecological traps (Gates and Gysell 1978), and thereby affecting population source/sink dynamics. It is also important to emphasise that this study considered only the effects of individual pipeline RoW on the bird communities adjacent to them. It did not consider how the overall abundance of pipelines, and other disturbances, over the entire landscape affected the regional abundance of bird species. Information on effects at different scales is critical when analysing the effects of human disturbance on wildlife (e.g., Tewksbury et al. 1998).

2.5 Literature Cited:

Achuff, P.L. 1994. Natural Regions, Subregions and Natural History Themes of Alberta. A Classification for Protected Areas Management. Protected Areas Report No. 2. Prepared for Parks Services, Alberta Environmental Protection, Edmonton, AB., 72 pp.

Aeibischer, N.J., P.A. Robertson and R.E. Kenward 1993. Compositional analysis of habitat use from animal radio-tracking data. Ecology **74**(5): 1313-1325.

Alberta Environmental Protection (AEP) 1998. The Boreal Forest Natural Region of Alberta.

Fahrig, L. 1999. Forest loss and fragmentation: Which has the greater effect on persistence of forest-dwelling animals. *In* J.A. Rochelle, L.A. Lehmann and J. Wisniewski (eds.) Forest Fragmentation: Wildlife and Management Implications. Brill, Leiden, Boston, Koln. Pp. 87-95.

Gates, J.E. and L.W. Gysel 1978. Avian nest dispersion and fledging success in field-forest ecotones. Ecology **59**(5): 871-883.

Johnson, E.A. 1992. Fire and Vegetation Dynamics: Studies from the North American Boreal Forest. Cambridge University Press, Cambridge.

Kremsater, L. and F.L. Bunnell 1999. Edge effects: theory, evidence and implications to management of western North American forests. *In* J.A. Rochelle, L.A. Lehmann and J. Wisniewski (eds.) Forest Fragmentation: Wildlife and Management Implications. Brill, Leiden, Boston, Koln. Pp. 117-153.

Marchak, M.P. 1995. Logging the Globe. McGill-Queen's University Press. Montreal and Kingston, PQ and ON. 404 p.

Morneau, F., G. J. Doucet, M. Giguère and M. Laperle 1999. Breeding bird species richness associated with a powerline right-of-way in a northern mixed forest landscape. The Canadian Field Naturalist **113**(4): 598-604.

Ralph, C.J., J.R. Sauer and S. Droege, technical editors 1995. Monitoring Bird Populations by Point Counts. Gen. Tech. Rep. PSW-GTR-149. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 187p.

Schmiegelow, F.K.A. and S.J. Hannon 1993. Adaptive management, adaptive science and the effects of forest fragmentation on boreal birds in northern Alberta. Transactions 58th North American Wildlife and Natural Resources Conference: 584-598.

Schmiegelow, F.K.A. and S.J. Hannon 1999. Forest-level effects of management on boreal songbirds: the Calling Lake fragmentation studies. *In* J.A. Rochelle, L.A. Lehmann and J. Wisniewski (eds.) Forest Fragmentation: Wildlife and Management Implications. Brill, Leiden, Boston, Koln. Pp. 201-221.

Schmiegelow, F.K.A., C.S. Machtans and S.J.Hannon 1997. Are boreal birds resilient to forest fragmentation? An experimental study of short-term community responses. Ecology **78**(6): 1914-1932.

Small, M.F. and M.L. Hunter jr. 1989. Response of passerines to abrupt forest-river and forest-powerline edges in Maine. Wilson Bulletin **101**(1): 77-83.

SPSS Inc. 2000. SPSS for Windows version 10.0. Chicago, IL.

Tewksbury, J.J., S.J. Hejl and T.E. Martin 1998. Breeding productivity does not decline with increasing fragmentation in western landscape. Ecology **79**(8): 2890-2903.

Chapter 3: Effects of Pipeline Rights-of-Way on Depredation of Artificial Nests

3.1 Introduction:

Depredation of nests has been implicated as an important factor in the reduced success of many species of forest nesting birds in fragmented and developed landscapes in North America (Gates and Gysel 1978, Wilcove 1985) and in Europe (Andrén 1992). Edges created by forest loss and fragmentation may change both biotic and abiotic factors within the adjacent forested area. As a result, bird and mammal communities may change, with an increased number of species associated with open areas, as well as those with mixed-habitat requirements (Gates and Gysel 1978). Overall density of birds can also increase, resulting in crowding and increased competition with forest species (Schieck et al. 1995). Such alterations may also result in higher numbers, and novel species, of both avian and mammalian nest predators (Andren 1992, Keyser et al. 1998). These predatory species may foray into the forest, preying on the eggs and nestlings of forest passerines (King et al. 1998). However, much of the foundational research on these issues was conducted in deciduous forests of Eastern North America (e.g., Wilcove 1985), and direct extrapolation of these results to Western boreal forests is not valid (Hannon 1993).

The use of artificial nests has become popular for experimentation on the effects of edges on relative rates of nest depredation in different habitat types, patch sizes and at various distances from edge (see Major and Kendal 1996 for a review). Nevertheless, there has been controversy in recent years over methods used to evaluate depredation rates on forest nesting birds (Paton 1994, Haskell 1995). Haskell (1995) suggests that some methods are biased because of the type of eggs used to sample depredation rates. For example, Japanese quail (*Coturnix japonica*) or chicken eggs, which are often used in experiments, are larger than the eggs of passerine birds, and, as a result, may be very difficult for small mouthed predators to break. This results in an underestimation of the importance of some predator species, such as mice and voles. If predator communities differ greatly in composition between treatments in an experimental study, then false conclusions may be drawn with respect to the overall threat of nest depredation to forest nesting birds. Thus, evaluation of the predator community is very important when interpreting results from these types of studies (Major and Kendall 1996). As a result of poor consistency between studies, and poor examination of assumptions and limitations of artificial nest experiments, data collected using artificial nests should be treated as only preliminary (Major and Kendall 1996).

Artificial nest studies do not necessarily reflect depredation rates on real nests (Paton 1994), due to differences in detectability and attractiveness to predators of artificial vs. real nests, and reproductive success is frequently underestimated (Major and Kendal 1996). If statements are to be made about rates on real nests, then comparative studies using both real and artificial nests must first be conducted. One additional note of caution about reproductive success measures from any study of depredation is that in a recent study of White-throated Sparrow nests (*Zonotrichia albicollis*), 79 percent of all nest depredation occurred at the hatchling stage rather than at the egg stage (K. Hannah pers. com.). However, the value of artificial nest studies lies in the ability of researchers to measure relative rates of nest depredation between experimental treatments, and to measure the relative importance of different predator species or guilds in a community.

Many studies of nest depredation, including those evaluating effects of patch size and distance from edge, have been conducted in forest patches embedded in agricultural landscapes, while those done in forest dominated landscapes usually evaluate effects of forest practices such as clearcut edges. Little is known of the effects of permanent linear features, such as roads or pipeline rights-of-way (RoW), on edge-related nest depredation in forested landscapes (but see Song and Hannon 1999).

In this study, I set out to determine: 1) the extent to which pipeline RoW in the boreal forest affected rates of nest depredation in adjacent forests, 2) the distance into the forest that any effects were exhibited, and 3) if various widths of RoW differentially influenced these effects. I attempted, through the use of plasticine eggs, to determine how the predator community was affected by RoW, and if changes in the predator community were consistent with changes observed in overall depredation rates. Specifically, I predicted that: 1) depredation rates would be higher at edges than in contiguous forest, 2) the predator community would be different near edges, with higher numbers of small mammals, such as mice, and lower numbers of forest associated species, such as squirrels and mustelids and 3) that these effects would be more prevalent near wider RoW due to the increased area of novel (grassy) habitat found there.

3.2 Methods:

The nest depredation study was carried out on the same study sites used for sampling the bird community (Chapter 2). The sites were located in aspen dominated boreal mixedwood forests between 80 and 110 years old, in the Gold Creek area, about 40 km south of Grande Prairie Alberta (see Figure 1.1, Chapter 1). Each site was positioned adjacent to pipeline RoW in four different width categories; 15-16 meters, 22-24 meters, 32-33 meters and > 50 meters. Three sites were surveyed in each of these width classes, for a total of 12 sites. In each site, artificial nests were placed along 600 meter transects parallel to the RoW, in each of four locations; within five meters of edge, 50 meters from edge, 100 meters from edge, and at control areas, 500 meters from edge. On each transect, 20 nests were placed about 25 meters apart, alternating between ground scrapes and shrub nests, for a total of 80 nests per site. Ground scrapes consisted of a depression made in the leaf litter, and shrub nests were commercially available canary nests (10 cm diameter) wired in shrubs 1-2 meters above the ground. In each nest, two plasticine eggs made to resemble the eggs of typical passerine species (approx. 1.5 X 1.2 cm oval) were placed. This enabled me to determine what animals were attacking the nests, based on the markings left behind by teeth or bills. The nests were placed at four sites simultaneously, one in each width class, in each of three time periods, during the spring and summer of 1999. They were checked for predator activity after five days, and again, when they were removed, after 10 days. Identified predators were placed into four groups; 1) small mammals (mice, voles), 2) intermediate mammals (squirrels, chipmunks, small mustelids), 3) large mammals (large mustelids, bears) and 4) avian (jays, magpies etc.).

Vegetation was evaluated for this study using the same data as presented in Chapter 2 of this thesis.

3.2.1 Data Analysis:

All data were tested for normality prior to analysis, and non-parametric tests were used where appropriate. I used α of 0.10 for all nest depredation analyses to reduce the possibility of Type II errors (e.g., Schmiegelow et al. 1997). Overall depredation rates were calculated for each transect by dividing the number of disturbed nests in each nest category (ground or shrub) by the total number of nests of that category on the transect. This standardized the rates of depredation, allowing for nests that were not relocated after the exposure period. To assess whether overall depredation rates differed significantly between the two nest types, ground and shrub, I performed a t-test . I tested for differences in rates at various distances from edge (5, 50, 100 and 500 metres) with ANOVA, including all transects in the experiment (N = 48), with distance from edge as a factor in the model, and site as a co-variate to test for spatial autocorrelation. Analysis of RoW width effect was conducted separately for each distance from edge, including only one transect per site in the ANOVA model (N = 12 for each distance).

To test for differences in depredation rates among predator types, proportions of disturbed nests depredated by each of the four predator groupings were calculated for each nest type, at each distance from edge, and for each width class of RoW. All proportional data were transformed using an arcsine $\sqrt{p}$, to account for the unit sum constraint associated with proportional data (Aeibischer et al. 1993). Subsequent analyses were performed separately for each nest type. ANOVA was used to test for differences in depredation rates for each predator type. Distance effects were analysed including distance from edge as a factor and site as a co-variate (N = 48 for each predator type). I then tested for width effects for each distance from edge, with RoW width as a factor(N = 12 for each predator type).

Post-hoc multiple comparison were conducted using a Bonferroni test, and all analyses were performed using SPSS Version 10.0 (SPSS Inc. 2000).

3.3 Results:

Nests located in shrubs experienced significantly higher rates of depredation than those located in ground scrapes ($p = 0.040$). I therefore performed all subsequent analyses separately for each of the two nest types. Site was a significant covariate in the overall model when testing for effects of distance from RoW edge on shrub nests ($F = 8.2$, $p = 0.006$), indicating potential spatial autocorrelation within sites, but no such pattern was detected for ground nests ($F = 2.2$, $p = 0.148$). Nevertheless, neither shrub nests nor ground nests showed any effect of distance from edge on depredation rate ($p = 0.804$ and 0.462, respectively; Figure 3.1). However, shrub nests showed a strong effect of width when only edge (5 metres from edge) transects were included in the analysis ($F = 24$, $p = 0.015$; Figure 3.2). Ground nests did not show this effect at edge transects ($F = 0.44$, $p = 0.728$; Figure 3.2). No other distances from edge showed an effect of RoW width for either nest type.

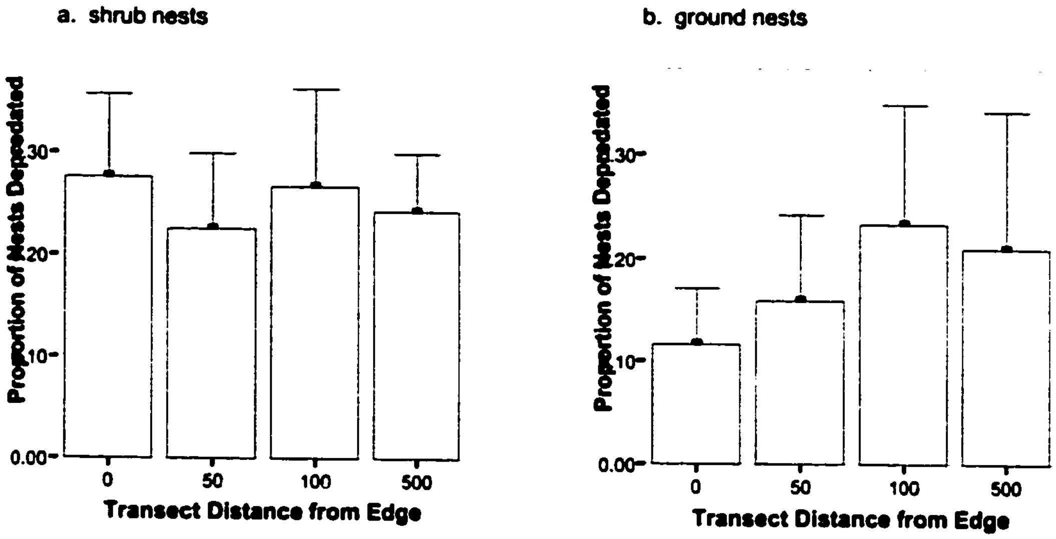


Figure 3.1: Proportion of a) shrub nests, and b) ground nests depredated after 10 days exposure at various distances from RoW edges in boreal forest south of Grande Prairie, Alberta, 1999 (p = 0.837 and 0.474 respectively). All sites included in the analysis. Error bars represent 90 % confidence intervals.

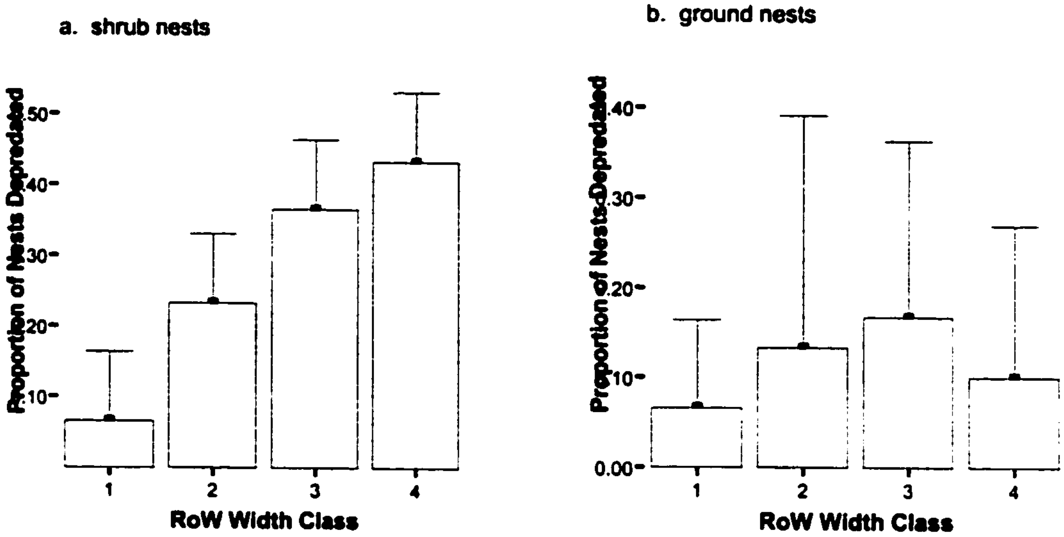


Figure 3.2: Proportion of nests depredated on edge transects only, between the four width classes of RoW after 10 days exposure, for a) shrub nests, and b) ground nests in boreal forest south of Grande Prairie, Alberta, 1999 ($p < 0.001$ and $p = 0.728$, respectively). Error bars represent 90% confidence intervals. Bonferroni post hoc tests for a) indicate homogeneous groups of width classes (1); (2,3); (3,4).

I could not identify predators of many of the depredated nests, due to lost nests or eggs, or unidentifiable markings on the eggs. There were no significant differences in depredation rates by any predator type, for either nest type, at any distance from RoW edge ($F = 0.19$ to 1.9, $p = 0.901$ to 0.183). Effects of spatial autocorrelation were negligable based on site as a co-variate. Width effects were observed on shrub nests for both small mammals and large mammals ($F = 2.9$, $p = 0.078$ and $F = 4.8$, $p = 0.020$, respectively; Figure 3.3). Large mammals showed significantly higher rates of depredation associated with RoW width 2, over width classes 3 and 4, while width class 1 was similar to all others (Figure 3.3b). Ground nests showed width effects for both small and intermediate mammals (F = 7.2, p = 0.005 and F = 4.7, p = 0.021, respectively). Post-hoc multiple comparisons indicated that, for both predator types, RoW width classes 1, 4 and 2 were similar, as were width classes 2 and 3. Width class 1 had the lowest depredation rate, followed by widths 4, 2 and 3 (Figure 3.4).

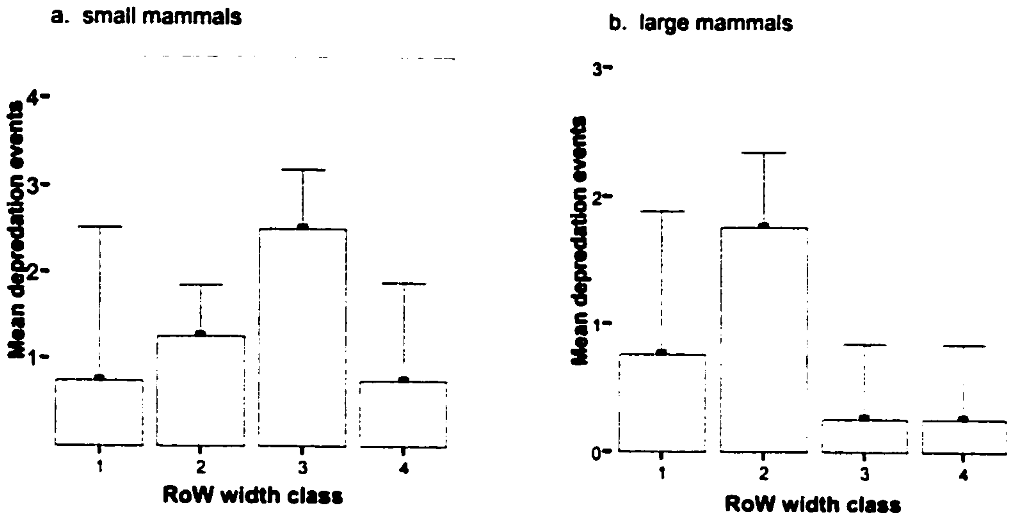


Figure 3.3: Mean number of depredation events on shrub nests by a) predator type 1 (small mammals) and b) predator type 3 (large mammals) between width classes of RoW in boreal forest south of Grande Prairie, Alberta, 1999 (p = 0.078 and 0.020 respectively; homogenous groups of width classes for b) are (1,2) and (1,3,4)). Error bars represent 90% confidence intervals.

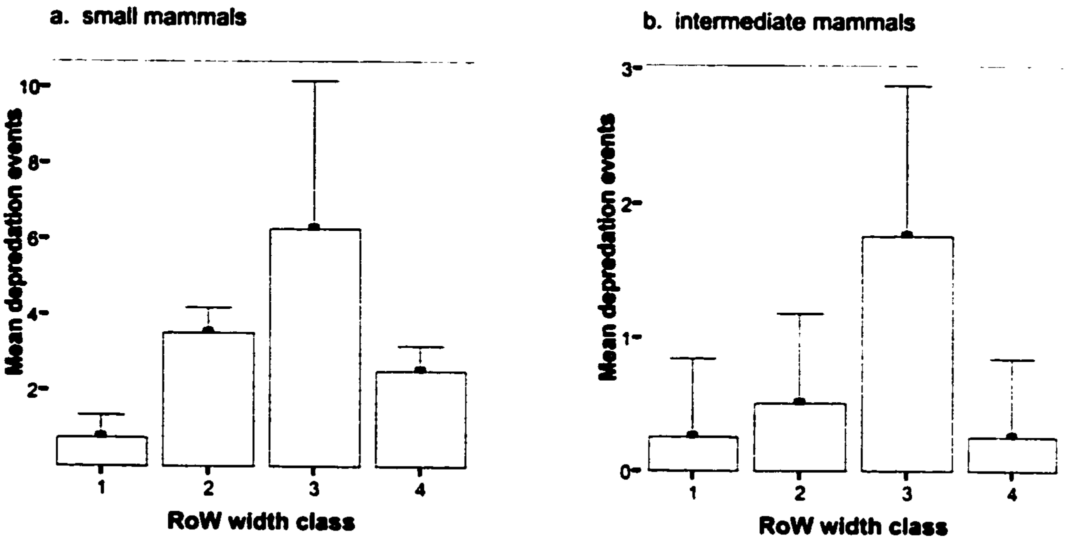


Figure 3.4: Mean number of depredation events on ground nests for a) predator type 1 (small mammals) and b) predator type 2 (intermediate mammals) between width classes of RoW in boreal forest south of Grande Prairie, Alberta, 1999. (p = 0.005 and 0.021 respectively; homogeneous groups for a) and b) are (1,2,4) and (2,3)). Error bars represent 90% confidence intervals.

Differences in vegetation structure are reported in Tables 2.1 and 2.2, Chapter 2. Although vegetation structure did differ in RoW plots and plots at the immediate edges of RoW when compared to control plots, I did not detect significant differences in nest depredation rates at various distances from RoW edges. Vegetation differences among RoW widths were found only for the within RoW plots. Of particular interest are differences in grass cover and shrub cover within the RoW, with significantly more grass found in the wider classes (widths 3 and 4) of RoW, and significantly less cover of shrubs within the RoW in the widest class (width 4).

3.4 Discussion:

This study revealed no instances where the distance from the edge of RoW accounted for significant differences in depredation rate. This was true for both ground and shrub nests, in contrast to Rudnicky and Hunter (1993), who found that shrub nests at clearcut edges showed higher rates of depredation than ground nests, and higher rates than shrub or ground nests in the forest interior. Song and Hannon (1999) found higher depredation rates in ecotones between aspen forests and seismic lines compared to contiguous forest in boreal Alberta in one year of a two year study, and higher rates at aspen/spruce ecotones in the other year, emphasizing the temporal and spatial variation in boreal forest ecosystems. Other studies indicate that proximity to edge does not strongly affect overall rates of depredation, despite changes in the predator community (Haskell 1995, Keyser et al. 1998).

In this study, although there were no differences in depredation rates based on proximity to edge, an interesting trend emerged with respect to the effect of RoW width. There were highly elevated rates of depredation, on shrub nests, on edge transects adjacent to very wide RoW when compared to rates along narrow RoW. Reasons for this are likely associated with changes in the predator community that result from the introduction of novel habitat associated with RoW. The wide RoW may be attracting greater numbers, or novel species of predators, due to the extent and the composition of the new habitat. The significant differences between width classes found in grass and shrub cover within RoW are consistent with this interpretation. Wider RoW have higher percent cover of grass, and lower percent cover of shrubs.

It is possible that predator species normally found in contiguous forest, such as red squirrels, pine marten and some rodent species, are avoiding RoW edges (e.g., Song and Hannon 1999), possibly due to increased risk of predation to themselves, or as a result of observed changes in vegetation structure. As a result, reduced numbers of predators normally associated with forest habitat may be found there. At the same time, potential predator species that are normally associated with grassland type habitats may be increasing in number wherever sufficient habitat exists to support populations. This may be true only for the wider RoW, as indicated by the vegetation analysis. Some predators, such as avian ones, may not perceive the narrower RoW as being gaps in the forest, or, they may prefer larger gaps in the forest cover for other purposes, i.e. visibility or other sources of food. In any case, changes in the predator community near wide RoW are potentially having a significant effect on the success rate of songbird nests.

The dissimilar rates of nest depredation among RoW widths that we observed along edges were not exhibited at any other distance from edge. This edge effect is, therefore, occuring within 50 meters of the forest edge, consistent with most past research on this problem (e.g., Paton 1994), and consistent with the vegetation patterns found in this study. Finer scale study is required to determine more precise distances from edge at which this effect is observed.

Analysis of the predator community in this study is not conclusive, because identification of predator species was not possible in almost half of the cases, contributing to relatively small sample sizes. There are, however, some interesting trends. Depredation by small mammals (mice, voles etc.) was similar at all distances from edge when all sites were considered. However, when only edge transects were included in the analysis, there was a width effect exhibited for shrub nests, with the narrowest RoW having the lowest depredation rates. Small mammal species inhabiting the wider RoW may be contributing to this effect, which is consistent with my predictions, and may be a result of the higher amounts of grass cover found in wider RoW. Results from other studies indicate that changes in small mammal communities do occur at or near induced edges. Sekgororoane and Dilworth (1996) found elevated numbers for all species combined, and in particular for deer mice (*Peromyscus maniculatus*), in ecotones 6-10 years old (post harvest) in New Brunswick. Bayne and Hobson (1998) also found elevated numbers of deer mice at edges of farm woodlots, when compared to the interior of those woodlots. Other species of small mammals have also shown responses to forest/field and forest/cutblock edges (e.g., Manson et al. 1999). Large mammal predators (large weasels, bears) actually exhibited an opposite effect to small mammals in this study, with the highest rates associated with the narrower widths of RoW. However, sample sizes for large mammals were quite small, and the effects, although statistically significant, should be interpreted conservatively. In the case of ground nests, a similar pattern was evident for both small mammal predators and intermediate mammal predators (squirrels, chipmunks), with lower rates of depredation associated with the narrow widths of RoW. The highest rates of depredation for these two predator types are associated with RoW in width class 3 (32-34 meters wide).

Overall, results from this artificial nest study indicate that very wide RoW are detrimental to the reproductive potential of forest birds in forests adjacent to the RoW. In particular, birds that build cup nests in low shrubs may be affected, which includes many neotropical migrant species such as Mourning Warbler, Magnolia Warbler, Canada

Warbler, Least Flycatcher and Red-eyed Vireo. Many of these species are those considered most at risk from anthropogenic disturbance (e.g. Smith 1993). Bird abundance data from this study do not suggest that these species are consistently less abundant immediately adjacent to RoW (see Tables 2.2 and 2.3), however these depredation results suggest the potential for forests next to RoW to function as population sinks, or ecological traps (Gates and Gysel 1978). Birds will attempt to breed in forests adjacent to pipeline RoW, perceiving them to be suitable breeding habitat, but lowered reproductive success in these areas may cause recruitment levels to be low. Recruitment levels below the natural death rate result in a declining population, which may, in turn, cause local extinctions.

Clearly, more information is necessary on actual reproductive success of bird species of concern near RoW edges. However, the preliminary information gained here does indicate that wide RoW, planted with commercial grass mixes, are changing the predator communities sufficiently to warrant concern over the effects on breeding forest birds. In the absence of irrefutable evidence, efforts should be made to reduce RoW widths where possible. However, reducing RoW width may not always be the best solution to reducing the effects of fragmentation on birds, particularly when it becomes necessary to construct greater numbers of narrow RoW. The effects of regional abundance of RoW on songbird populations must be considered when management decisions are made, an issue not thoroughly addressed with this research. Large areas of undisturbed forest are likely necessary to maintain populations of some forest dependent species (Askins et al. 1987).

3.5 Literature Cited:

Aeibischer, N.J., P.A. Robertson and R.E. Kenward 1993. Compositional analysis of habitat use from animal radio-tracking data. Ecology **74**(5): 1313-1325.

Andrén, H. 1992. Corvid density and nest predation in relation to forest fragmentation: a landscape perspective. Ecology **73**(3): 794-804.

Askins, R.A., M.J. Philbrick and D.S. Sugeno 1987. Relationship between the regional abundance of forest and the composition of forest bird communities. Biological Conservation **39**: 129-152.

Bayne, E.M. and K.A. Hobson 1998. The effects of habitat fragmentation by forestry and agriculture on the abundance of small mammals in the southern boreal mixed wood forest. Canadian Journal of Zoology **76**(1): 62-69.

Gates, J.E. and L.W. Gysel 1978. Avian nest dispersion and fledging success in field-forest ecotones. Ecology **59**(5): 871-883.

Hannon, S. 1993. Nest predation and forest bird communities in fragmented aspen forests in Alberta. *In* D.H. Kuhnke (ed.) Birds in the Boreal Forest. Proceedings of a workshop held March 10-12, 1992, Prince Albert, Saskatchewan. For. Can. Northwest Reg., North. For. Cent., Edmonton, Alberta. Pp. 127-136.

Haskell, D.G. 1995. A reevaluation of the effects of forest fragmentation on rates of bird-nest predation. Conservation Biology **9**(5): 1316-1318.

Keyser, A.J., G.E. Hill and E.C. Soehren 1998. Effects of forest fragment size, nest density, and proximity to edge on the risk of predation to ground-nesting passerine birds. Conservation Biology **12**: 986-994.

King, D.I., R.M. Defraaf and C.R.Griffin 1998. Edge-related nest predation in clearcut and groupcut stands. Conservation Biology **12**: 1412-1415.

Major, R.E. and C.E. Kendal 1996. The contribution of artificial nest experiments to understanding avian reproductive success: a review of methods and conclusions. Ibis **138**: 298-307.

Manson, R.H., R.S. Ostfeld and C.D. Canham 1999. Responses of a small mammal community to heterogeneity along forest-old-field edges. Landscape Ecology **14**(4): 355-367.

Paton, P.W.C. 1994. The effect of edge on avian nest success: how strong is the evidence? Conservation Biology **8**(1): 17-26.

Rudnicky, T.C. and M.L. Hunter jr. 1993. Avian nest predation in clearcuts, forests and edges in a forest dominated landscape. Journal of Wildlife Management **57**(2) 358-364.

Schieck, J., K. Lertzman, B. Nyberg and R. Page 1995. Effects of patch size on birds in old-growth montane forests. Conservation Biology **9**(5): 1072-1084.

Schmiegelow, F.K.A., C.S. Machtans and S.J.Hannon 1997. Are boreal birds resilient to forest fragmentation? An experimental study of short-term community responses. Ecology **78**(6): 1914-1932.

Sekgororoane, G.B. and T.G. Dilworth 1996. Relative abundance, richness and diversity of small mammals at induced forest edges. Canadian Journal of Zoology **73**(8): 1432-1437.

Smith, A. 1993. Ecological profiles of birds in the boreal forest of western Canada. *In* D.H. Kuhnke (ed.) Birds in the Boreal Forest: Proceedings of a Workshop Held March 10-12, 1992 in Prince Albert, Saskatchewan. Northern Forestry Centre, For. Can., NW Region. Edmonton, AB. pp 14-26.

Song, S.J. and S.J. Hannon 1999. Predation in heterogeneous forests: a comparison at natural and anthropogenic edges. Ecoscience **6**(4): 521-530.

SPSS Inc. 2000. SPSS for Windows version 10.0. Chicago, IL.

Wilcove, D.S.,1985. Nest predation in forest tracts and the decline of migratory songbirds. Ecology **66**(4): 1211-1214.

Chapter 4: Gap Crossing by Boreal Forest Birds in the Post-Fledging Period

4.1 Introduction:

Fragmentation of the boreal forest from human caused disturbance is an important issue for wildlife conservation and management. Habitat loss resulting from industrial activity is the focus of much research, but how remaining habitat is configured is also an important consideration. The division of remaining habitat into 'islands' can pose threats to many species, particularly those that are shy of human activity, and those that are not highly mobile. In extreme cases, division of populations can occur, which affects the flow of genetic material between isolated groups.

Forest birds, although highly mobile, may be reluctant to cross gaps created in forest cover by human industrial activity. Birds may resist crossing open areas due to increased risk of predation (Lima and Dill 1990). Studies of birds' willingness to cross gaps have indicated that as the width of a habitat gap increases, birds are less likely to cross in response to call playbacks (Desrochers and Hannon 1997, Rail et al. 1997). Birds may also use forested detours, when available, rather than fly a shorter distance across an open area (Desrochers and Hannon 1997, St. Clair et al. 1998).

Some types of anthropogenic disturbance in forests create permanent, uninterrupted gaps in forest cover. Roads, transmission corridors and pipeline rights-of-way (RoW) are examples of disturbances that are generally maintained in perpetuity, without regeneration of trees and large shrubs. These types of disturbance, because of their continuous, linear nature, also exclude forested detours that birds and other animals might use in crossing the gap. This may influence the ability of birds to disperse after fledging (Matthysen and Currie 1996), which may, in turn, affect their ability to locate potential breeding areas for the following year (Brewer and Harrison 1975, Mathyson and Currie 1996).

In this study, the willingness of birds to cross various widths of RoW during the post-fledging period was examined. The primary goals of the study were to: 1) determine if RoW are acting as a barrier to bird movement, 2) determine if various widths of RoW are acting as barriers to a varying extent, and examine possible thresholds of gap width that affect movement of birds and 3) examine the effectiveness of the methodology to examine these effects.

4.2 Methods:

4.2.1 Study Sites:

The study was carried out in the Gold Creek area, approximately 40 km south of Grande Prairie, Alberta (Figure 1.1, Chapter 1). Study sites were established at RoW in four width classes: 1) 15-16 meters, 2) 22-24 meters, 3) 32-34 meters and 4) > 50 meters. All RoW were located in aspen dominated mixed-wood forests, between 80 and 110 years of age. The RoW were all well established (> 5 years since construction), and had been planted with commercial grass seed mixes after construction. Re-colonization of native shrub species had occurred to some extent in all RoW, but shrubs and saplings in the RoW were all less than 3 meters in height, and sparsely distributed.

4.2.2 Bird Movement:

Data on willingness of forest birds to cross forest gaps were collected using playbacks of Black-capped Chickadee (*Poecile atricapillus*) mobbing calls. This method has been used successfully to elicit responses from a variety of species (Hurd 1996, Desrochers and Hannon 1997). At each site (N = 12; 3 replicates of each of 4 width classes), two sample points were established on the edge of the RoW, 400 meters apart. Playbacks were conducted during two time intervals: 08:00 - 12:00, and 18:00 - 22:00, between July 23 and August 9, 1999. At this stage in the breeding season, most juveniles have fledged and are moving around, and most adults are no longer territorial. The playbacks were conducted using a portable cassette player with 5W amplified speakers, set in the forest within 2-3 meters of the RoW edge. At one of the sample points during each visit, volume was controlled by varying the sound level recorded at the far side of each RoW (70 dB far side of RoW; digital sound meter). At the other sample point, calls were played at a standard, maximum volume, so sound level varied at the far side of RoW of various widths. The purpose of this was to assess whether choice to respond was influenced by the perceived distance from the source.

During the 10-minute playback interval, two observers were stationed approximately 20 meters on either side of the sound source, along the RoW edge, and watched for birds arriving at or near the speakers. Birds were considered to have responded to the calls if they were detected approaching the sound source within 10 meters, or if they moved to a point directly across the RoW from the sound source and vocalised, without crossing. All birds responding to the calls were recorded to species when possible, and classified by response type, i.e. whether they crossed the RoW, responded but failed to cross the RoW, or came from the forest adjacent to the sound source. Each site was visited four times: twice in the morning and twice in the evening, with a minimum of three days between each visit. Each point at a site was sampled twice with controlled volume and twice with uncontrolled (maximum) volume.

4.2.3 Statistical Analysis:

Differences between the number of responses in the morning and evening playbacks, and with controlled and uncontrolled volume, were conducted using t-tests. The volume tests were conducted using all sites, as well as separately for each width class of RoW. For these analyses, I treated each visit as independent, as the objective was to assess methodology, rather than to test for treatment effects. To test for RoW width effect on the willingness of birds to cross, proportions of the total responses that actually crossed the RoW were calculated for each site, over all visits. Least significant difference (LSD) tests were used post-hoc to determine pairwise differences between the four width classes of RoW. Alpha was set at 0.10 for all tests, to reduce the possibility of type II errors (e.g., Schmiegelow et al. 1997).

4.3 Results:

In all, 26 identifiable species responded to call playbacks (Table 4.1). There were no significant differences in the total number of responses between morning and evening playbacks, although morning playbacks had slightly higher numbers of responses (N =

48, p = 0.109). There were also no differences between total number of responses with controlled and uncontrolled volume (N = 48, p = 0.196), however, differences were observed when individual width classes was tested separately. Controlled volume playbacks at the two smaller width classes of RoW had significantly fewer responses than the uncontrolled playbacks, likely due to the reduced volume used to achieve 70dB at the far side of the RoW (n = 12, p = 0.083 for both width 1 and 2; Figure 4.1).

Table 4.1: Alphabetical listing of all bird species, including unknowns, which responded to playbacks of Black-capped Chickadee mobbing calls in Gold Creek, 40 km south of Grande Prairie, Alberta, 1999.

Species	Frequency	Percent
American Redstart (*Setophaga ruticilla*)	10	6.1
American Robin (*Turdus migratorius*)	2	1.2
Black-capped Chickadee (*Poecile atricapillus*)	64	39.0
Black and White Warbler (*Mniotilta varia*)	2	1.2
Canada Warbler (*Wilsonia canadensis*)	2	1.2
Chipping Sparrow (*Spizella passerina*)	1	0.6
Golden-crowned Kinglet (*Regulus satrapa*)	1	0.6
Gray Jay (*Perisoreus canadensis*)	4	2.4
Lincolns' Sparrow (*Melospiza lincolnii*)	5	3.0
Magnolia Warbler (*Dendroica magnolia*)	4	2.4
Mourning Warbler (*Oporornis philadelphia*)	1	0.6
Northern Waterthrush (*Seiurus noveboracensis*)	1	0.6
Pine Siskin (*Carduelis pinus*)	1	0.6
Red-breasted Nuthatch (*Sitta canadensis*)	2	1.2
Red-eyed Vireo (*Vireo olivaceus*)	19	11.6
Ruby-throated Hummingbird (*Archilochus colubris*)	1	0.6
Blue-headed Vireo (*Vireo solitarius*)	1	0.6
Swainsons' Thrush (*Catharus ustulatus*)	1	0.6
Tennessee Warbler (*Vermivora peregrina*)	2	1.2
Unknown species	11	6.7
Warbling Vireo (*Vireo gilvus*)	2	1.2
White-breasted Nuthatch (*Sitta carolinensis*)	1	0.6
Western Tanager (*Piranga ludoviciana*)	1	0.6
White-throated Sparrow (*Zonotrichia albicollis*)	8	4.9
Yellow-bellied Sapsucker (*Sphyrapicus varius*)	2	1.2
Yellow Warbler (*Dendroica petechia*)	9	5.5
Yellow-rumped Warbler (*Dendroica coronata*)	6	3.7
Total	164	100.0

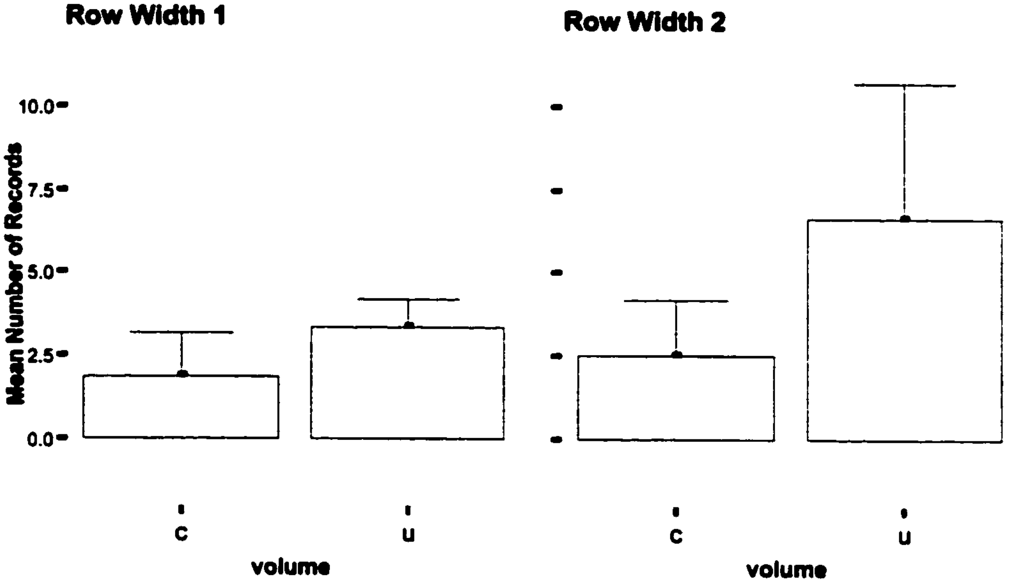


Figure 4.1: Mean number of responses of all species between controlled (c), and uncontrolled (u) volume of playbacks, for RoW width classes 1 (15-16 meters) and 2 (22-24 meters. Gold Creek region, south of Grande Prairie, Alberta, summer 1999. Error bars represent 90% confidence intervals.

Results for the effect of width on willingness to cross using proportions of responses crossing the RoW were not significant between width classes of RoW (p=0.231), however, LSD tests indicated that width class 2 had significantly higher proportions of birds willing to cross than did width class 3 (p=0.059; Figure 4.2). .

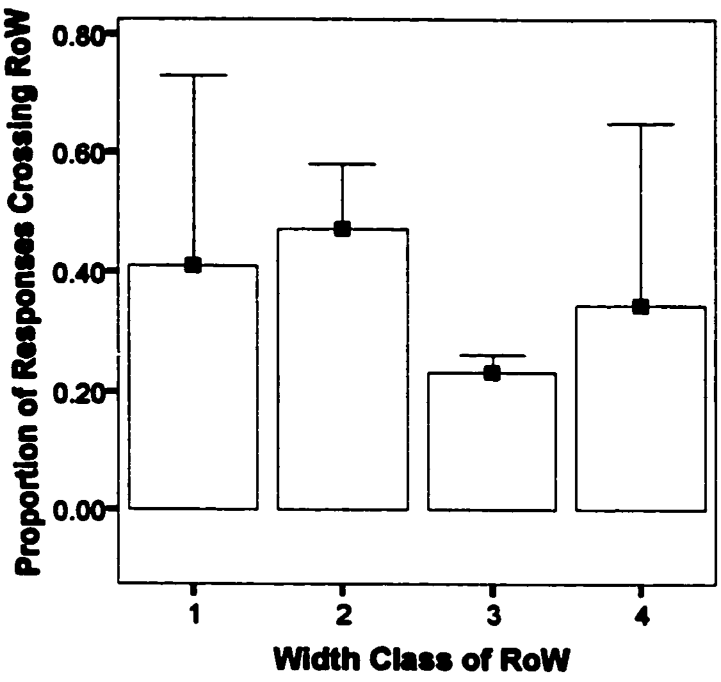


Figure 4.2: Proportion of birds that crossed pipeline RoW of various widths (p=0.059; n=3 for each width class), in order to respond to call playbacks south of Grande Prairie, Alberta, summer 1999. Proportions are the number of responding birds that crossed the RoW, divided by the total number of respondents. Error bars represent 90% confidence intervals.

4.4 Discussion:

Overall, the playbacks of Chickadee mobbing calls were successful in attracting a variety of bird species. In total, there were 164 responses by individual birds or intra-specific groups of birds, including responses by 26 identifiable species. Most responses (39%) were by Black-capped Chickadees. Desrochers and Hannon (1997), in a larger scale study, achieved 421 responses by 37 different species in the boreal forest of Quebec, also in the post-fledging period, and using Chickadee mobbing calls.

It is probable that responses to mobbing calls vary not only between species, but also in response to different habitat configurations. In addition, responses by some species may be difficult to assess, due to lack of vocalization or simply cryptic behaviour. This is particularly true for birds approaching the sound source from the opposite side of the RoW, and then failing to cross. This type of response, potentially indicative of a reluctance to venture into open habitat, and therefore of particular interest to this study, may have been underestimated, as observers were stationed on the side of the RoW where the sound source was located. This presents further difficulty in evaluating the behaviour of birds not crossing RoW. Bias may have been present due to the variation in widths of RoW: birds responding from the far side would be much easier to locate and identify across a 15 meter RoW than across an 80 meter RoW.

The proportion of birds that actually crossed RoW in order to respond was highest for 22-24 m RoW, and lowest for 32-34 m RoW (width classes 2 and 3, respectively). While the general trend was that smaller numbers of birds were willing to cross the wider RoW, these two width classes were the only ones that were significantly different. Overall, there were no differences in the number of responses between controlled and uncontrolled volume experiments, so the distance across the RoW did not seem to affect the likelihood of some type of response. The controlled volume playbacks were designed to eliminate the effect of distance across the RoW on the likelihood of birds to respond from the far side. Given the possible bias in the detectability of birds on the far side of RoW of different widths, it is possible that the proportion of birds willing to cross the wide RoW was actually smaller than the data indicate, and the effect of RoW width may be larger than indicated by the results presented here. A stronger experimental design would include positioning observers on both sides of the RoW.

Other studies of gap crossing behaviour in birds suggest a possible threshold distance of about 50 meters between forest cover, over which birds become reluctant to move. For example, St. Clair et al. (1998) found that resident winter birds were reluctant to venture more than 25 meters from a forest edge, equivalent to a 50 meter gap, in order to respond to mobbing calls. Desrocher and Hannon (1997), found that gaps less than 30 meters wide had little impact on willingness of post-fledging period birds to cross them, but wider gaps (70 meters and 100 meters) had significant effects. While I found some reluctance to cross RoW as narrow as 22-24 meters, I cannot determine whether this was strictly an affect of the RoW, or whether some birds within forest would be similarly reluctant to approach, i.e. I did not have adequate controls.

If the presence of wide RoW in an area are having some effect on the movement capability of forest songbirds, the question then becomes - what is the overall effect on population persistence? It is possible, in extreme cases, that divisions could occur in populations, but it is unlikely that movement across even the widest RoW is completely eliminated.

The presence of forested strips as movement corridors for wildlife is a controversial issue in wildlife management (e.g., Simberloff et al. 1992, Mann and Plummer 1995). However, data from this and other studies (e.g., Desrochers and Hannon 1997, St. Clair et al. 1998), indicate that boreal forest songbirds may benefit from the availability of forested routes to cross large gaps in forest cover. Construction of RoW in the future, particularly very wide RoW, should include leaving periodic forested corridors to ameliorate potential restrictions in movement and dispersal of forest birds, and other forest wildlife species. This could be accomplished by passing the pipeline under a forest corridor, as is now done when crossing waterways or other barriers. Studies also indicate that narrow gaps in forest cover pose a less significant barrier than wide gaps, so periodically narrowing the RoW may also facilitate wildlife movement. This latter strategy would reduce some of the cost associated with diagonal drilling techniques that would be necessary to leave an entire forested corridor across the RoW. However, further studies are necessary to assess the efficacy of these management techniques.

4.5 Literature Cited:

Brewer, R. and K.G. Harrison 1975. The time of habitat selection by birds. Ibis **117**: 521-522.

Desrochers, A. and S.J. Hannon 1997. Gap crossing decisions by forest songbirds during the post-fledging period. Conservation Biology **11**(5): 1204-1210.

Hurd, C.R. 1996. Interspecific attraction to the mobbing calls of Black-capped chickadees (*Parus atricapillus*). Behavioral Ecology and Sociobiology **38**: 287-292.

Lima, S.L. and L.M. Dill 1990. Behavioral decisions made under the risk of predation: a review and prospectus. Canadian Journal of Zoology **68**: 619-640.

Mann, C.C. and M.L. Plummer 1995. Are wildlife corridors the right path? Science **270**: 1428-1430.

Matthyson, E. and D. Currie 1996. Habitat fragmentation reduces disperser success in juvenile nuthatches *Sitta europaea*: evidence from patterns of territory establishment. Ecography **19**: 67-72.

Rail, J.F., M. Darveau, A. Desrochers and J. Huot 1997. Territorial responses of boreal forest birds to habitat gaps. The Condor **99**: 976-980.

Simberloff, D., J.A. Farr, J. Cox and D.W. Mehlman 1992. Movement corridors: conservation bargains or poor investments. Conservation Biology **6**(4): 493-504.

St. Clair, C.C, M. Belisle, A. Desrochers and S. Hannon 1998. Winter responses of forest birds to habitat corridors and gaps. Conservation Ecology [online] **2**(2): 13. Available from the Internet. URL: http://www.consecol.org/vol2/iss2/art13.

Chapter 5: Summary, Management Recommendations and Future Research

5.1 Summary:

In this study, I set out to measure how linear disturbances, specifically pipeline rights-of-way (RoW) of different widths, might be affecting forest passerine birds in Alberta's boreal forest with respect to habitat loss and fragmentation effects. In chapter 2 of this thesis, I examined the bird communities present in forests adjacent to pipeline RoW of different widths, and compared them to bird communities in control forests not closely associated with RoW. In addition, I evaluated the abundance of passerine bird species individually, to identify those that may be affected, either beneficially or adversely, by the presence of RoW. I predicted higher bird abundance and greater species richness near edges, and that these effects would increase with RoW width. I also predicted that RoW edges would differentially affect species in three ways: 1) some species would occur in higher abundance or even exclusively at edges, 2) some species would be relatively unaffected by proximity to edge and 3) some species would occur in higher abundance or exclusively in control forests, well removed from human disturbance.

In chapter 3, I examined one 'edge effect' that has been implicated in the decline of many passerine bird species: increased depredation of nests by edge and open area associated predators. I used an artificial nest experiment to sample depredation activity at different distances from the edge of RoW, and near edges of RoW of different widths. I attempted to quantify, through the use of plasticine eggs, how the predator community is affected by proximity to edge and width of RoW. I predicted that depredation would be higher near edges and that this affect would increase with RoW width due to larger areas of grass dominated habitat. I also expected that the predator community at edges, particularly adjacent to wide RoW, would have greater numbers of small mammal predators and lower numbers of intermediate size mammals, such as squirrels and mustelids, that are more closely associated with contiguous forest.

In chapter 4, I discussed some preliminary data that I collected on the potential for RoW of different widths to act as movement barriers, possibly affecting juvenile dispersal and territory establishment. I attempted to lure birds across RoW using call playbacks, in order to measure the willingness of birds to cross gaps of different widths in the absence of alternate routes. Based on previous literature (e.g., Desrochers and Hannon 1997, St. Clair et al. 1998), I predicted that gaps wider than 50 meters would pose a significant barrier to movement.

5.1.1 Bird Community:

Some of the data collected on the bird community indicated that there is elevated bird abundance near edges of RoW, however species richness was not greatly affected by edge. Nevertheless, individual species do, as predicted, respond differently to edge. A few species were more abundant on control plots than near edges, but results were inconsistent between two sampling methods used in this study, and differences were generally small. Edge avoidance by interior forest species does not appear to be prevalent based on these results. There were, however, some species that clearly preferred edges to interior forest, so differences in the bird community between interior forest and edge forests do exist.

RoW width did not have a large effect on the bird community with respect to abundance or species richness, and individual species showing differences in abundance near RoW of different width numbered only three using both sampling methods. Black-capped Chickadees and Ovenbirds had higher abundance adjacent to the narrowest RoW, and Yellow Warblers had highest abundance near intermediate widths.

5.1.2 Nest Depredation:

Nest depredation was significantly higher adjacent to wide RoW compared to narrow ones, and analysis of the predator community indicated this was due to increased numbers of small mammal predators, such as mice. The vegetation analysis showed significantly elevated grass cover in the wider RoW, possibly a factor contributing to the higher numbers of small mammal predators. Wide RoW, planted with grass, are contributing to depredation of bird nests in nearby forests, possibly to the point of creating population sinks for some species of birds.

5.1.3 Bird Movement:

Birds showed some reluctance to cross all widths of RoW in this study, however as I did not control for reluctance to approach the sound source by also tracking the response of individuals in continuous forest, my ability to draw conclusions is limited. In general, however, there was an increasing, but non-significant trend for reluctance to cross to increase with increasing RoW width. Potential bias in the detectability of birds at various widths also confounded results.

5.1.4 Population Dynamics:

Data from this study did not indicate that RoW had large effects on abundance or species richness in the breeding bird community, however, there is potential for effects on populations based on the success of breeding individuals. The data I collected on the bird community did not address the issue of population source/sink dynamics, however the potential exists for creation of ecological traps (Gates and Gysel 1978). An ecological trap is created when factors exist that cause increased mortality of young, reducing recruitment into the population to levels below the natural death rate. This situation can cause declines in populations and local extinctions if there is insufficient high quality habitat available to replenish populations. The nest depredation rates found in this study clearly show the potential for population sinks to exist adjacent to wide RoW. The addition of species into the bird community as a result of RoW construction could add to the potential for ecological traps. Novel species attracted to the grassland type habitat, and breeding in forests near edges can increase competition for other species present. Several species were found to be more abundant near the edges in this study, and some data indicate higher overall bird abundance at edges. Nest success may be further reduced by the reduction in available resources resulting from competition. Measurements of the breeding bird community over a short time period, along well established RoW, would not detect declining populations, and would not detect species that have already been severely impacted by industrial development.

5.2 Management Recommendations:

The effect of RoW width is important when considering options for development of RoW in the future. If, as this research suggests, wide RoW are causing changes in the predator community associated with the RoW itself, and therefore, the edges, then the disruption of ecological processes in adjacent forests may be significant. Wide RoW, which offer a substantial expanse of grassland type habitat within the forest matrix, could be responsible for the intrusion of species not normally present in forested areas, or large increases in population of mammals that are usually associated with smaller or less permanent gaps in forest cover. Based on this research, I recommend that RoW width should be reduced wherever it is logistically feasible to do so.

Reducing the width of RoW may involve creating more of them in situations where multiple pipes are necessary, thus it is important to consider the effects of this at a landscape level. Large numbers of pipeline RoW of any size in a given area may have effects on animal populations that studies of effects on individual RoW do not address. The research described here looked only at effects of individual RoW, and more work must be done considering animal populations in landscapes containing different levels of overall development, before conclusions can be drawn. One such conclusion is whether it is more beneficial, from a conservation perspective, to produce multiple narrow RoW in place of a single wide one containing multiple pipes. The emphasis now, without knowledge of regional effects of development, should be on improving technology and construction techniques to reduce the space required when building pipelines.

In order to facilitate movement of birds, and possibly other wildlife species, very wide gaps in forest cover should be avoided. Pipeline RoW, which can be over 100 meters in width, are maintained in perpetuity with little vegetation over 2 or 3 meters in height, and may run without interuption for hundreds of kilometers. Management in the future should consider the creation of some type of forested corridors to facilitate movement of wildlife. Past research suggests that even a periodic reduction in width may facilitate movement. Some boreal forest birds are reluctant to cross gaps wider than about 50 meters (e.g., St. Clair et al. 1998) and will detour significant distances in order to utilise routes with forest cover (Desrocher and Hannon 1997).

This study does not directly address the reclamation techniques used in RoW, however some of the data presented here leads to speculation about the vegetation used to re-plant after RoW construction. The nest depredation data I collected indicate high rates of nest depredation adjacent to very wide RoW - the same RoW which have the highest levels of grass cover, and the lowest levels of shrub and forb cover. The relative amount of nest depredation by small mammals (mice and voles) was also highest adjacent to the widest RoW, so it is possible that the vegetation content of the RoW, in addition to the larger area, is responsible for changes in the predator community.

5.3 Future Research:

Future studies of breeding bird communities should emphasise population dynamics rather than abundance and richness measures. Monitoring population dynamics in birds is logistically difficult, as nests are hard to find in most cases, and monitoring and measuring nest success is time consuming. In order to obtain sufficient information to make valid statements about population trends or source/sink dynamics, studies will have to be large scale, and long term. In addition, studies need to address effects of the regional abundance of anthropogenic disturbance, rather than just local effects. Studies assessing local effects, such as this one, may be useful in addressing larger scale problems, if the information is used in concert with other studies, or in cumulative effects assessment.

Larger scale studies are also necessary to assess the effects of human development on rare species. Species that occur in low density, whether as a result of human habitat alteration or as a natural state, will not be adequately sampled with short term, localised studies. Several species that occur in the area that this study was conducted, and whose conservation status is in question, were not encountered in sufficient numbers to be included in the analysis of single species abundance, and some species I expected to find, were not detected at all.

The research I carried out on nest depredation indicates that there are potential negative effects of wide RoW on bird breeding success. Analysis of the predator community and vegetation enabled me to speculate about what might be responsible for the elevated rates of nest depredation I found, however, future studies on this subject should consider predator identification a high priority. Many of the depredated nests in this study were disturbed by unknown predators, and more definitive statements about causes could have been made if greater success had been achieved in identifying them.

Finally, the gap-crossing experiments I performed showed some promise for assessing the potential of RoW to act as movement barriers, however a more comprehensive assessment is required. Such a study should monitor response at various times throughout the breeding season, and include appropriate controls.

5.4 Literature Cited:

Desrochers, A. and S.J. Hannon 1997. Gap crossing decisions by forest songbirds during the post-fledging period. Conservation Biology **11**(5): 1204-1210.

Gates, J.E. and L.W. Gysel 1978. Avian nest dispersion and fledging success in field-forest ecotones. Ecology **59**(5): 871-883.

St. Clair, C.C, M. Belisle, A. Desrochers and S. Hannon 1998. Winter responses of forest birds to habitat corridors and gaps. Conservation Ecology [online] **2**(2): 13. Available from the Internet. URL: http://www.consecol.org/vol2/iss2/art13.