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The relative effects of road traffic and forest cover on anuran populations

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ABSTRACT

Road traffic and the loss of forests are both known to have negative effects on anurans. However, the relative importance of these two predictors is poorly understood because forest cover in the landscape is usually negatively correlated with the density of roads and traffic. To evaluate the independent effects of traffic and forest cover, we selected 36 ponds near Ottawa, Canada, at the center of four landscape types: low forest/low traffic; low forest/high traffic; high forest/low traffic; and high forest/high traffic, where traffic and forest cover were measured within 100–2000 m of the edge of each pond. We surveyed all ponds in 2005 and re-surveyed a 23-pond subset in 2006. The negative association between species richness and traffic density was stronger (partial $R^2 = 0.34$; $P < .001$) than the positive association of species richness with forest cover (partial $R^2 = 0.10$; $P > .05$) in the landscape. Three of six common species showed stronger associations with traffic density than with forest cover – *Bufo americanus*, *Rana pipiens*, and *Hyla versicolor*; two species – *Pseudacris crucifer* and *Rana sylvatica* – showed stronger associations with forest cover than with traffic; while *Rana clamitans* showed similar associations with traffic and forest cover. Our results show that the overall negative effect of traffic on anuran populations in northeastern North America is at least as great as the negative effect of deforestation, and also that the relative effects of these two predictors on anuran abundance vary between species.

1. Introduction

Two of the most important landscape scale predictors of anuran presence and abundance are forest cover and roads, particularly high traffic roads (Fahrig et al., 1995; Vos and Chardon, 1998; Cushman, 2006). However, the relative importance of forest cover and roads or traffic in the landscape is poorly understood, mainly because road density and forest cover are usually correlated (Houlahan and Findlay, 2003). Understanding the relative importance of the traffic density and forest cover in the landscape on anuran populations has important management implications. For example, the main conservation priority for a species relatively unaffected by forests but negatively affected by traffic would be to preserve landscapes with low traffic densities irrespective of forest cover. Our goal in this study was to quantify the relative effects of traffic density and forest cover on the anuran species richness and relative abundances near Ottawa, Canada.

Amphibian populations are declining globally, mainly due to the loss and degradation of natural habitat (Stuart et al., 2004). Many species require forest habitat in the landscape for part of their life cycle (Wilbur, 1980). In addition, many

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populations are thought to exhibit metapopulation dynamics (Hecnar and M'Closkey, 1996; Pope et al., 2000; Marsh and Trenham, 2001), so moist forest habitats allowing dispersal among local populations are important for long-term population persistence (deMaynadier and Hunter, 1999). Indeed, forest cover within a landscape extending 100–3000 m from breeding ponds and wetlands is positively associated with the presence and abundance of many species of amphibians (e.g. Laan and Verboom, 1990; Hecnar and M'Closkey, 1998; Knutson et al., 1999; Guerry and Hunter, 2002; Houlahan and Findlay, 2003; Herrmann et al., 2005).

The necessity of moving between multiple habitats and of re-colonizing breeding sites means that many amphibians are also vulnerable to roads in the landscape. Studies have shown negative correlations between: amphibian species richness in breeding sites and paved road density (e.g. Findlay et al., 2001); anuran pond occupancy and road density (Vos and Chardon, 1998); and anuran relative abundance and traffic density (Fahrig et al., 1995; Carr and Fahrig, 2001).

The negative effect of roads on anurans is probably due mainly to direct mortality (roadkill). Fahrig et al. (1995) showed that high traffic two-lane paved roads had a much larger effect on anuran abundance than low traffic two-lane paved roads. Mortality rates for anurans on high traffic roads are higher than on low traffic roads (Hels and Buchwald, 2001), and forestry roads with very low traffic have no effect on anuran movements (deMaynadier and Hunter, 2000). In addition, incidences of very large numbers of road-killed anurans are well-documented (e.g. Ashley and Robinson, 1996), and studies have shown strong population-level effects of traffic density (Carr and Fahrig, 2001) and high traffic roads on anurans (Van Gelder, 1973; Vos and Chardon, 1998). Therefore, total traffic on roads in the landscape likely has a greater effect on anurans than total length of roads in the landscape.

There are several reasons why the relative importance of the effects of roads and forest loss on anuran populations is largely unknown. Numerous landscape scale studies have looked at both effects (Findlay and Houlahan, 1997; Hecnar and M'Closkey, 1998; Knutson et al., 1999; Lehtinen et al., 1999; Houlahan and Findlay, 2003; Herrmann et al., 2005), but as Houlahan and Findlay (2003) point out, forest cover and paved road density are frequently highly correlated, making it impossible to determine which has the greater effect. Studies that include urban areas (e.g. Knutson et al., 1999; Lehtinen et al., 1999; Trenham et al., 2003) inevitably result in high correlations between road density and urbanization. Urbanization has severe negative effects on anuran populations (e.g. Rubbo and Kiesecker, 2005; Gagné and Fahrig, 2007), due to a variety of factors of which roads are only one. Low variation among sites in predictor variables can also bias conclusions regarding relative effects of roads versus forest loss. In southwestern Ontario, forest cover in the landscape had a larger effect on amphibian species richness than the distance to the nearest paved road (Hecnar and M'Closkey, 1998). Paved road density and forest cover were uncorrelated in this study; however, most of these sites were far from high traffic roads, so the full potential effect of traffic was not measured. Finally, all previous studies of the effects of both roads and forest loss on anurans used road density (e.g. Lehtinen et al., 1999; Findlay et al., 2001) or distance from roads (Hecnar and M'Closkey, 1998) to measure road effects, which likely underestimates the full effect of road traffic on anurans.

Our purpose was to quantify the relative importance of the full effects of deforestation and roads on anuran populations. We accomplished this by selecting landscapes in which forests and traffic were uncorrelated and in which there was a large range in variation of both forest cover and traffic, and by using traffic density rather than road density to measure the road effects.

2. Methods

2.1. Site selection

We conducted this study in rural areas of eastern Ontario and western Quebec within 100 km of Ottawa, Ontario, Canada in the spring and summer of 2005 and 2006. We surveyed 36 permanent ponds in 2005 and a 23 pond subset of these in 2006 (Fig. 1). Ponds were at the center of 1500 m radius landscapes with varying amounts of forest cover and traffic density. Fifteen hundred metres contains the dispersal range of most species examined (Oldham, 1966; Schroeder, 1976; Berven and Grudzien, 1990; Seburn and Seburn, 1998). Sampling ponds were at least 3 km apart to avoid overlap of landscapes and thus avoid pseudoreplication. To minimize the correlation between forest and traffic, we selected ponds in four landscape types: low forest/low traffic, low forest/high traffic, high forest/low traffic, and high forest/high traffic (Fig. 2). 'Low forest' landscapes had $\leqslant$35% forest cover and 'high forest' landscapes had $\geqslant$60% forest cover within 1500 m of the pond. 'Low traffic' landscapes contained only two-lane municipal and county roads (paved and unpaved), and 'high traffic' landscapes contained at least one major intercity highway or motorway within 1500 m of the pond (Appendix A).

2.2. Anuran field surveys

Nine anuran species are present in the study area: wood frog (*Rana sylvatica*), spring peeper (*Pseudacris crucifer*), western chorus frog (*P. triseriata*), northern leopard frog (*R. pipiens*), American toad (*Bufo americanus*), gray treefrog (*Hyla versicolor*), green frog (*R. clamitans*), mink frog (*R. septentrionalis*) and bullfrog (*R. catesbeiana*).

In 2005 we conducted three visual day surveys and eight auditory night chorus surveys to assess the relative population sizes of all anuran species at or near the sample ponds. Chorus surveys were conducted between April 12 and July 27, with at least two surveys during each species' peak breeding season. Chorus surveys followed a modified version of the Marsh Monitoring Protocol (Bishop et al., 1997). Surveys started half an hour after sunset and finished before midnight. We surveyed each pond for 5 min, and recorded the number of calling males at or within 100 m of the pond in four abundance classes: 0 – no individuals calling; 1 – individuals can be counted and calls are not overlapping; 2 – calls of <15 individuals, some overlap of calls; 3 – calling individuals too numerous to count or $\geqslant$15 individuals calling, calls over-