**MEASURING THE EFFECTS OF FOREST EXTENT AND ROAD TRAFFIC ON ANURAN
POPULATIONS**

By

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of the requirements for the degree of

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ABSTRACT:

Landscape ecologists have made large strides in the last 15 years in understanding the effect that landscape structure has on the abundance and persistence of organisms. However, conducting research at the landscape scale brings with it a number of methodological challenges. In this thesis, I use careful site selection and novel analytical techniques to examine the effects of forest extent and road traffic on anuran populations, and, more generally, examine how methodological issues affect landscape-scale inference. I address four questions : 1) What is the effect of experimental design on landscape-scale inference? 2) What are the relative effects of road traffic and forest extent on anuran populations? 3) What are the combined effects of a major highway and the forest extent near it on anuran populations? 4) What is the road effect zone of a major intercity highway for anurans?

I showed that sub-optimal study design at the landscape scale – particularly incomplete sampling across the possible range of values in a predictor variable and correlations between landscape-scale predictors - is likely to have a major impact on landscape-scale inference. I then showed that the negative effect of road traffic is three times as great as the landscape-scale effect of deforestation on anuran species richness in eastern Ontario when these two predictor variables are considered independently. Having established that road traffic has an important negative effect on anurans, I then focused on better understanding how roads affect wildlife. First, I showed that a novel measure of the combined effects of roads and habitat loss on wildlife - accessible habitat - was a better predictor of anuran species richness near a major highway (Highway 401) than considering distance to the highway and habitat amount alone. I then showed that the

negative effect of Highway 401 on anuran populations extends at least 500 m into the landscape. Overall, my results suggest that sub-optimal study design has likely led to an underestimate of the true effect of roads on wildlife. More generally, careful study design is necessary for landscape-scale studies to continue to provide meaningful guidelines for conservation.

This dissertation is dedicated to the memory of my father,

Dr. Kurt Dieter Eigenbrod (1940 - 2005).

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GENERAL INTRODUCTION:

Theoretical background

Over the last 20 years, ecologists have become aware that organisms are not affected just by local ecological processes, but also by what is happening at larger scales, and that the scale of effect will depend both on the organism and process being examined (Wegner and Merriam 1979; Urban et al 1987; Brown and Maurer 1989; Fahrig and Merriam 1994; Forman 1995; Gaston and Blackburn 2000). Landscape ecology, broadly defined by Turner (2005) as the 'reciprocal interactions between spatial heterogeneity and ecological processes', has grown enormously as a discipline over this time period. This definition encompasses both the European regional/landscape planning orientated approach to the discipline (Troll 1950), and the more ecological North American approach – 'the causes and consequences of spatial pattern at variable spatial scales defined by the organism or process of interest' (Turner 2005). This dissertation falls under the latter definition of landscape ecology, and, more specifically focuses on the effects of landscape structure on organisms.

Conducting research at the landscape scale brings with it a number of major methodological challenges (Klopatek and Gardner 1996; Brennan et al 2002; McGarigal and Cushman 2002). In landscape ecology, size (scale), grain (resolution) and heterogeneity of the landscape are organism and/or process specific (Wiens 1989; Goodwin and Fahrig 1998), so the first challenge is selecting a scale and level of heterogeneity that is appropriate for the question of interest. For example, in a study focusing on the effects of habitat loss on beetle abundance, the size of the landscape may

be less than a metre in diameter, and it may be necessary to differentiate between different species of grasses in defining what constitutes 'habitat' for this species. The landscape for a bird, on the other hand, would be measured in hectares or even square kilometres (Tittler 2008). For the bird, it would likely not be necessary to differentiate between species of grasses when looking at the effects of habitat loss on abundance, but rather (for example) at the amount of grassland, deciduous forest, coniferous forest and urbanization in the landscape. A second challenge is that different components of landscapes are often not independent of each other (McGarigal and Cushman 2002). For example, as the amount of forest in a landscape increases, the amount of other land cover types will necessarily decrease, creating correlations among landscape variables. It is also known that measures of habitat fragmentation, such as patch area and patch isolation, are highly correlated with the total amount of habitat in the landscape (Tischendorf 2001). A third challenge is that the range of values of a landscape-scale variable found across a set of landscapes is likely to differ both between sets of landscapes and between variables within landscapes. For example, a large range of road densities is likely to exist across a set of landscapes that encompass an urban-agricultural gradient; however, the range of forest cover across this set of landscape is likely to be quite low. Consequently, a study using this set of landscapes will have less inferential strength to detect an effect of forest cover than an effect of road density on the abundance of some organism, and thus could not be used to compare the relative strengths of these two predictors. Given their inherently spatial nature, landscape ecology studies are also vulnerable to issues of spatial non-independence (Legendre 1993; Dale and Fortin 2002; Lichstein et al 2002) that have also been well-documented in the macroecological literature (e.g. Diniz-Filho et al 2003).

Failure to account for these methodological issues decreases inferential strength and may even lead to incorrect conclusions.

A consensus is now emerging after 15 years of research that the composition of the landscape (i.e. the amounts of various types of land cover and land use) is more important than the configuration of the landscape (e.g., fragmentation per se) (Andren 1994; Fahrig 2003; Ewers and Didham 2006). Both empirical (e.g. Trzcinski et al 1999) and theoretical work (Fahrig 2001) indicate that loss of habitat in particular is likely the single most important factor affecting organisms at the landscape scale, and likely the main driver in the global extinction crisis (Hughes et al 1997; Foley et al 2005). Indeed, one of the central tenets of ecology – the species-area relationship (Watson 1859, Arrhenius 1921), a fundamental concept in MacArthur and Wilson's theory of island biogeography (1963, 1967) – postulates that the number of species is inextricably linked to the amount of habitat available (Diamond and May 1976; Rosenzweig 1995).

However, care must be taken when using this 'habitat fragments as islands' approach (e.g. Brooks et al 2002), as island biogeography theory assumes that islands are surrounded by an inhospitable sea, which is generally not true in terrestrial systems (Haila 2002; Ewers and Didham 2006). The matrix (non-habitat portion of the landscape) differs from oceans in how it impacts organisms, mainly because matrix quality can vary enormously between landscapes (Ewers and Didham 2006). The matrix can reduce gene flow and dispersal, much like the water between oceanic islands; however in terrestrial systems dispersal rates may vary between matrix types (e.g. Roland et al 2000). A benign matrix can also provide resources that can compensate for habitat loss (e.g. Perfecto and Vandemeer 2002), while a hostile matrix can greatly reduce occupancy and

abundance of many species in the landscape through negative edge effects (reviewed in Ries et al 2004) or direct mortality.

Indeed, it is known that some negative matrix effects such as pesticides, urbanization, and roads can be very large for many organisms. Agricultural intensification – which includes greater chemical and fertilizer inputs – is effectively an increase in matrix hostility, and has been shown to lead to decreases in the diversity of a wide variety of taxa (Matson et al 1997; Benton et al 2003; Norris 2008). Urban areas also constitute an extremely hostile type of matrix for many species (e.g. Czech et al 2000; Dunford and Freemark 2005; Duguay et al 2007; Gagné and Fahrig 2007). Roads and the motor vehicle traffic on them also have very large impacts on wildlife populations, due both to their pervasiveness and the number of taxa affected by this ‘sleeping giant’ of conservation biology (Forman and Alexander 1998; Forman et al 2003; Coffin 2007). For example, approximately 20% of the land area of the conterminous United States is within 127 m of a road, and 83% of the land area is within 1061 m of a road (Riitters and Wickham 2003). Taxa negatively affected by roads and traffic include amphibians (e.g. Carr and Fahrig 2001; Semlitsch et al 2007), snakes (Andrews and Gibbons 2005), turtles (e.g. Gibbs and Steen 2005), ground beetles (e.g. Keller and Largiader 2003), bumblebees (Bhattacharya et al 2003), European badgers (Clarke et al 1998), small mammals (e.g. Oxley et al 1974), bobcats and coyotes (Riley et al 2006), roe deer (Kuehn et al 2007), bighorn sheep (Epps et al 2005) and grizzly bears (Mace et al 1996).

However, despite the mounting evidence that roads have severe negative effects on many taxa, the importance of the negative effect of this stressor relative to habitat loss

is unknown. This is largely due to the correlation between natural habitat and roads – many landscapes with high road density have little habitat and vice versa (e.g. Houlahan and Findlay 2003). Given the large effects on populations that roads have for some groups such as anurans (e.g. Fahrig et al 1995) and turtles (e.g. Steen and Gibbs 2004), it is possible that the negative effects of roads exceed the effects of habitat loss for some organisms. With limited resources available for conservation, it is clearly important to know which of these two stressors has a greater effect on populations.

In addition to not knowing the relative effects of habitat loss and roads, interactions between roads and habitat loss are very poorly understood. Landscape-scale effects of roads are generally measured independently of the effects of habitat loss through indicators such as road density (e.g. Houlahan and Findlay 2003), distance to the nearest road (e.g. Gutzwiller and Barrow 2003), or traffic density (e.g. Carr and Fahrig 2001). However, it seems likely that in many cases there will in fact be an interaction between the effects of roads and habitat loss in the landscape, as roads may reduce the availability of portions of the habitat in a landscape by restricting access to it. Failing to account for this interaction, if present, could lead to an underestimate of both the effects of roads and of habitat loss on an organism affected by both.

We also have a poor understanding of how far from the edge of a road the negative effects extent - the ‘road effect zone’ of Forman and Deblinger (2000) - partly because methods for precisely quantifying the road effect zone are not yet well developed (Coffin 2007). For example, we do not know the distance to which the negative impacts of the thousands of kilometres of intercity highways in North America extend for most taxa. Given the increasing number of studies documenting strong effects of intercity

highways on wildlife (e.g.; Clevenger and Waltho 2000; Forman et al 2003; Riley et al 2006), this omission is an important gap in our knowledge of the effects of roads on wildlife.

My dissertation aims to answer four main questions: 1) What is the effect of experimental design on landscape-scale inference? 2) What are the relative effects of road traffic and deforestation on anuran populations? 3) What are the combined effects of a major highway and the forest cover near it on anuran populations? 4) What is the road effect zone of a major intercity highway for anurans?

Justification of study taxa

I focus on amphibians in my dissertation because this group is particularly vulnerable to the effects of habitat loss and roads/traffic (Cushman 2006). They are also thought to be among the most threatened taxon globally, with over a third of species threatened with extinction (Stuart et al 2004). The most important driver of this decline is thought to be the loss and degradation of habitat, with forests the major habitat type for amphibians (Stuart et al 2004). A large reason for the vulnerability of amphibians to the above stressors is the complex life cycle exhibited by many species. Most amphibians require terrestrial habitats in addition to their aquatic breeding habitats (Wilbur 1980), and many annually move large distances across the landscape between their terrestrial and aquatic habitats. Forests are particularly important because many species require forest habitat in the landscape for the terrestrial component of their life cycle (Wilbur 1980), and forests facilitate dispersal among populations (deMaynadier and Hunter 1999). Effective dispersal across the landscape is particularly important for amphibians

as they often exhibit metapopulation (Sjögren 1994; Hecnar and M'Closkey 1996; Pope et al 2000; Marsh and Trenham 2001) or patchy population (Smith and Green 2005) dynamics, with local populations frequently undergoing extinction (Hecnar and M'Closkey 1996) and requiring re-colonization through dispersal. High connectivity of the landscape – the degree to which a landscape facilitates or hinders movement through it (Taylor et al 1993; Tischendorf and Fahrig 2000) – is thus vital for the long-term persistence of amphibian populations. Roads, especially those with high traffic volumes, have a large negative effect on many species of anurans by both reducing connectivity of isolated populations and by reducing the sizes of populations near high traffic roads through direct mortality (Fahrig et al 1995; Vos and Chardon 1998; Hels and Buchwald 2001; Carr and Fahrig 2001; Cushman 2006; Eigenbrod et al 2008).

Maintaining healthy populations of amphibians, even widespread species that are not in immediate danger of extinction, is vital because declines of this group can have large-scale and lasting ecosystem-level effects (Whiles et al 2006). Amphibians are among the most abundant vertebrates overall, often constituting a major component of biomass, and transferring large quantities of energy between aquatic and terrestrial ecosystems (Burton and Likens 1975; Gibbons et al 2006). Amphibians can also play pivotal roles in aquatic food webs, acting as both predators and prey (Hecnar 2004). In addition, the larval (tadpole) stage of ranid anurans has been shown to have a major impact on algal community structure (Dickman 1968; Loman 2001). Finally, amphibians are frequently considered indicators of overall ecosystem health (Vitt et al 1991). This is because 1) their permeable skin makes them vulnerable to anthropogenic pollution; 2) and their requirement for both aquatic and terrestrial habitat combined with low vagility

relative to other vertebrates makes them especially vulnerable to habitat loss and fragmentation (Hecnar 2004).

In this thesis, I focused on six species with different levels of sensitivity to deforestation and road traffic: the wood frog (*Rana sylvatica* LeConte), spring peeper (*Pseudacris crucifer* Wied-Neuwied), northern leopard frog (*Rana pipiens* Schreber), American toad (*Bufo americanus* Holbrook), gray treefrog (*Hyla versicolor* LeConte), and green frog (*Rana clamitans* Latreille). These species are common near Ottawa, Ontario and throughout much of the Great Lakes basin of eastern North America. Two species – the wood frog and spring peeper – are forest obligates that breed in ephemeral pools in early spring (Harding 1997). The other four species are less closely tied to forest cover in the landscape. The relationships between forest cover and the amount of forest in the landscape for the American toad and gray treefrog are poorly understood, as is discussed in detail in Chapter 1. The leopard frog is known to be strongly negatively affected by traffic volumes in the landscape, while the green frog has been shown to be less vulnerable to this stressor (Carr and Fahrig 2001). The effects of traffic on the other four species were unknown prior to completion of Chapter 2 of this thesis (Eigenbrod et al 2008), and *a priori* it seemed likely that the relatively mobile American toad and wood frog would be more vulnerable to road traffic than the spring peeper or gray treefrog (Jaeger et al 2005). I also included the less common western chorus frog (*Pseudacris triseriata* Wied-Neuwied), mink frog (*Rana septentrionalis* Baird) and bullfrog (*Rana catesbeiana* Shaw) in my estimates of species richness during my fieldwork in eastern Ontario.

CHAPTER 1: SUB-OPTIMAL STUDY DESIGN HAS MAJOR IMPACTS ON LANDSCAPE-SCALE INFERENCE (Adapted from Eigenbrod F, Hecnar SJ, Fahrig L Sub-optimal study design has major impacts on landscape-scale inference. In review)

1.1 Chapter summary: Landscape-scale studies can have a major impact on conservation planning, but the complexity and size of landscapes makes study design at this scale difficult. Brennan et al (2002) identified five potential pitfalls associated with designing landscape-scale studies: 1) selecting the incorrect spatial scale for the analysis; 2) using landscapes that overlap in space (non-independence); 3) using only a portion of the potential range of the landscape predictor variable(s) of interest; 4) failing to account for correlations among landscape predictor variables; and 5) the existence of broad-scale spatial trends confounding landscape-scale effects. I test how these five pitfalls affect the inferred relationships between the amount of forest in the landscape and the abundance of six species of anurans using a large ($n = 1141$) dataset from Wisconsin and Michigan, USA. I show that sub-optimal study design alone can be sufficient to cause a switch in the sign of the inferred relationship between a species response and landscape structure. The two pitfalls that had the greatest impact were 1) using only a portion of the potential range of a landscape predictor variable; and 2) correlations among landscape predictor variables. My results also suggest that inconsistencies in the literature about the inferred relationships between anuran presence and abundance and forest in the Great Lakes region are largely due to these sampling design issues.

1.2 Introduction:

Over the past 20 years, landscape ecology has led to major strides in understanding the impacts of landscape-scale human activities on biodiversity (Turner 2005). However, the complexity and size of landscapes can make study design at this scale difficult. Brennan et al (2002) identify five potential pitfalls associated with the design of landscape-scale analyses. These are: 1) selecting the incorrect spatial scale for the analysis; 2) using landscapes that overlap in space (non-independence) 3) using only a portion of the potential range of the landscape predictor variable(s) of interest; 4) failing to account for correlations among landscape predictor variables; and 5) the existence of broad-scale spatial trends confounding landscape-scale effects.

The scale at which an organism responds to the landscape varies greatly between species (Wiens 1989). If a landscape-scale study is conducted at a scale that is inappropriate for the species, this will reduce its power to detect the true effect of a predictor (Holland et al 2004). It is also possible that the sign of the response of a species to a landscape predictor will change with spatial scale, perhaps due to qualitatively different responses to the predictor for different stages in the species' life cycle (e.g. breeding vs. dispersal).

Overlapping landscapes can lead to non-independence of residuals, thus increasing the likelihood of making Type I errors by causing a systematic underestimation of confidence intervals (Legendre 1993). Overlapping landscapes can also lead to lower variation in the predictor variable (Brennan et al 2002), thus reducing the statistical power to detect an effect.

The chance of detecting an effect of a predictor will also be greatly reduced if only a portion of its potential range is considered (Brennan et al 2002). If there is a non-monotonic effect of a predictor, then a limited range of predictor variables could additionally lead to contradictory findings, as the slope of the relationship between the response and the predictor will vary depending on the predictor value.

Correlations among predictors are a problem throughout biology (e.g. Grafen and Hails 2002), but particularly so for landscape ecology (McGarigal and Cushman 2002) as it is impossible for any one landscape-scale predictor to occur independently of all other landscape-scale variables. High correlations among predictors mean it is impossible to know which of the related predictors are in fact responsible for a given effect on a species, and can lead to erroneous inferences. For example, road traffic in the landscape has large negative effects on anuran abundance (Carr and Fahrig 2001; Eigenbrod et al 2008a). A study in which road density and amount of forest cover are highly negatively correlated – as is often the case (e.g. Findlay et al. 2001) - may therefore show a positive effect of forest on a species, when in fact the true effect of forest on this species – independent of the effect of roads - is negative.

To control for correlations, investigators often use multiple regression models. This reduces the likelihood of making the type of incorrect inference described in the above example, but increases the likelihood of erroneously concluding that there is no effect of a predictor by reducing statistical power, because variation shared between predictors (where they co-vary) is not included in the estimates of the effect of each individual predictor (Grafen and Hails 2002).

Finally, Brennan et al (2002) point out that broad-scale spatial trends can mask finer-scale (e.g. landscape) patterns of interest. They suggest these large-scale trends can be controlled for by using residuals from the polynomial regression model with X and Y coordinates as the response (but see Freckleton (2002) for a critique of the use of residuals in ecology).

Brennan et al (2002) suggest that non-overlapping landscapes should be selected using a quasi-experimental, non-random approach in order to minimize correlations among landscape variables and to ensure a wide range of values in the predictor variables of interest, thus maximizing statistical power to detect an effect of landscape structure. However, logistical constraints, such as the availability of sampling locations, mean that less-than-ideal sampling designs are often unavoidable in landscape-scale studies. Given the impact that landscape ecology can have on conservation planning (Turner 2005), it is clearly important to know what impacts such sub-optimal sampling designs have on landscape-scale inferences. However, to date no study has explicitly evaluated this impact.

In this chapter, I examine how sampling design affects inferred relationships between landscape structure and species responses. As a test case, I evaluate the effects of the amount of forest cover in the landscape on the abundances of six species of anurans, using a large dataset from Wisconsin and Michigan, USA, and test the effects of Brennan et al's five pitfalls on this relationship.

The relationships between forest cover and anurans in the Great Lakes basin are a particularly suitable choice for this study because for 6 anuran species there are multiple published landscape-scale studies in this region (13 studies altogether), and for four of

these species the different studies give conflicting results (Table 1.1). Are these differences real or are they due to artefacts of experimental design?

1.3 Methods:

Data Sources

For the response variables, I used relative anuran abundance data from 1141 survey sites (hereafter referred to as the ‘full dataset’) gathered by two large-scale volunteer-based anuran monitoring programs - the Wisconsin Frog and Toad Survey and the Michigan Frog and Toad Survey (Fig. 1.1). The surveys use a very similar protocol (Mossman et al 1998). Trained volunteers conduct nocturnal call surveys under suitable weather conditions (warm humid nights with little wind) at or near a wetland (10 sites per route) three times a year (early spring, late spring and early summer). Each call survey lasts a minimum of 3 minutes in Michigan and 5 minutes in Wisconsin, with up to 10 minutes allowed in both cases so the observer can be confident that all calls were recorded. The estimated relative abundance of anurans is then assigned to one of 4 classes: 0 – not present; 1- present, few individuals, no overlap among calls, individuals can be counted; 2 – several individuals, some overlap among calls; number of individuals can be counted; 3 – many individuals, overlap among calls, number of individuals cannot be distinguished. All 1141 sites have at least 5 years of data between 1996 and 2002. I used the average of the maximum call index heard for each species at each site over time (based on between 5 and 7 years of data) (Knutson et al 1999) as the response for every analysis, as anuran populations are known to exhibit large year-to-year fluctuations (Pechmann et al 1991).

For the landscape predictor variables, I used the 2001 United States Geological Survey land cover dataset (30 m resolution) (Vogelmann et al 2001) which I reclassified using ArcGIS 9.1 (Environmental Systems Research Institute, Redlands, California, USA) to give six land cover classes: forest, wetland, crop, pasture, open water and development (roads, urbanization, quarries).

General approach

My approach to testing the five pitfalls discussed by Brennan et al (2002) was to run two analyses (or sets of analyses) per pitfall. In one analysis, I controlled for the pitfall, and the other in I did not. I then compared the value of the forest coefficient for the two analyses.

To obtain robust estimates of the forest coefficients and to test for significant differences between the forest coefficients when controlling vs. when not controlling for each pitfall, I used a randomization approach. For each analysis, I randomly selected 1000 subsets of 25 or 50 sites and ran the same statistical models for all 1000 subsets to obtain a distribution of the forest coefficient. I used the program FOCUS 2.3 (Holland et al 2004) to select the random subsets with the restriction that all sites were located at least 10 km from their nearest neighbour (non-overlapping landscapes at the 5 km scale) for all analyses except where I were testing for the impact of non-overlapping landscapes.

With 1000 subsets for each analysis, I expected up to 50 significant (25 positive and 25 negative) associations by chance alone at the 95 % confidence level. Thus, I only considered a species to have a statistically significant positive or negative association with forest cover in an analysis if 25 or more of the subsets showed significant ($\alpha = 0.05$)

positive or negative associations with forest cover. I considered a change from 25 or more significant positive association with forest cover to 25 or more significant negative associations with forest cover (or vice versa) to signify a shift in the sign of the forest coefficient. All statistical analyses were run using R 2.6 (R Development Core Team 2007).

Pitfall 1: Selecting the incorrect spatial scale for the analysis

To test for the effect of the scale at which the amount of forest cover in the landscape is measured on the forest coefficient, I ran simple linear regressions of anuran abundance on forest amount using 1000 randomly selected subsets of 50 datapoints from the full dataset ($n = 1141$), where forest amount was calculated at different scales: landscape radii of 500, 1000, 3000 or 5000 m.

Pitfall 2: Using landscapes that overlap in space

To determine the effect of overlapping landscapes on the forest coefficient, I compared the results of 1000 random subsets that were selected from the full dataset such that there was no overlap at the 5000 m scale (minimum distance to the nearest neighbour of each point of 10,000 m), with 1000 random subsets selected to maximize the overlap of landscapes. The 5000 m scale was chosen to test Pitfalls 2 to 5 as the results from testing Pitfall 1 showed that this was the scale at which the overall response to forest of the six species I examined was strongest, and that running the analyses at scales other than 5000 m did not qualitatively affect my findings.

Ideally, I would have selected all 50 sites for each of the 1000 random subsets in the second analysis to be within 10,000 m of each other (i.e. all landscapes overlapping with each other). However, the distribution of the sites in this study (Fig. 1.1) meant that this was not possible. Instead, I selected 1000 subsets of 50 sites, with each subset made up of several clusters of sites that were within 10,000 m of each other. For each subset, I first selected one site at random out of the full dataset and then selected all other sites that were within 10,000 m of this first site. I then randomly selected another site and all sites within 10,000 m of it, subject to the restriction that none of this second set of sites had already been selected as part of the first set of sites. I repeated this process until I had selected the necessary 50 sites for a subset. This approach gave a mean nearest neighbour distance of 1638 m for the 1000 subsets of 50 clustered points, as compared to a mean nearest neighbour distance of 37,753 m in the 1000 subsets where there was no overlap at the 5000 m scale. I then regressed the abundance of each of the 6 species on the amount of forest cover in the landscape at the 5000 m scale for each subset in both analyses.

Pitfall 3: Using only a portion of the potential range of the landscape predictor variable of interest

To evaluate the effect of the range of the amount of forest in the landscape on the relationship between anurans and the amount of forest cover, I compared the results of five datasets with varying ranges of forest cover in the landscape at the 5000 m scale. The first dataset consisted of sites where forest covered 0.5 to 15 % of the landscape (264 of 1141 sites), the second where forest covered 40 to 60 % of the landscape (200 of the 1141 sites), the third where forest covered 30 to 70% of the landscape (433 of the 1141 sites in

the full dataset), the fourth where forest covered 50 to 97 % (219 of 1141 sites) of the landscape, and the fifth where I placed no restrictions on the percentage of forest cover in the landscape (all 1141 sites, ranging in forest cover between 0.5 and 97%). For each dataset I then randomly selected 1000 subsets of 25 datapoints, and ran simple linear regressions of anuran abundance on forest amount for each species for each subset. I used only 25 datapoints per subset because of the relatively small number of sites from which I could choose the 1000 random subsets in the second ($n = 200$) and fourth ($n = 219$) datasets.

Pitfall 4: Failing to account for correlations among landscape predictor variables

As discussed in the introduction, correlations between roads and/or urban development and forest are particularly likely to affect the magnitude and sign of the forest coefficient. Indeed, the correlation between development and the amount of forest in the landscape at the 5000 m scale over all 1141 sites was $r = -0.43$. To test for the effects of correlations between forest cover and development (which is highly correlated with road density; $r > 0.8$ over all 1141 sites), I selected a 500 site subset of the original 1141 sites such that the Pearson correlation coefficient between the amount of forest and the amount of development at the 5000 m scale was the maximum possible: $r = -0.77$. I then selected a 727 site subset of the original 1141 sites such that the Pearson correlation coefficient between the amount of forest and the amount of development at the 5000 m scale was the minimum possible: $r = -0.05$. From each subset I then randomly selected 1000 subsets of 50 sites and ran both a simple linear regression of anuran abundance on forest amount and a multiple regression model of anuran abundance on forest amount and development.

Pitfall 5: The existence of broad-scale spatial trends confounding landscape-scale effects

To test for the effect of broad-scale spatial trends on the forest coefficient, I compared simple linear models of anuran abundance on forest cover to regressions of residual anuran abundance after controlling for spatial trends. To obtain residual anuran abundances, I ran a regression of anuran abundance on the X and Y coordinates of the sampling location and the interaction between X and Y. I then used the residuals from this first model as the response in a second regression of residual abundance on forest. I ran all analyses at the 5000 m scale using 1000 randomly selected subsets of 50 datapoints from the full dataset ($n = 1141$).

1.4 Results:

Descriptive statistics of the full data set

Over all 1141 sites, there was a positive trend in the relationship between the abundance of the wood frog and spring peeper vs. forest cover at the 5000 m scale, a negative trend for the leopard frog and American toad, and a possible positive trend for the gray treefrog and green frog (Fig. 1.2).

Pitfall 1: Selecting the incorrect spatial scale for the analysis

There was little evidence that the scale at which forest was measured affected the sign of the association of anurans with forest cover for any species except the green frog. The latter showed a negative association with forest cover at the 500 m and 1000 m scales, but a weak positive association with forest at the 3000 and 5000 m scales. There

were, however, differences among scales in strength of the relationship between anuran abundance and forest cover for four species: spring peeper, wood frog, leopard frog and American toad (Table 1.2).

Pitfall 2: Using landscapes that overlap in space

Overlapping landscapes decreased the strength of the positive association with the forest coefficient for the wood frog and spring peeper, and increased the negative association between forest cover and leopard frog abundance. The mean forest coefficient also increased for the gray treefrog and decreased for the American toad in the subsets with overlapping landscapes. However, there was so much variation around the mean coefficient for these species that this had little effect on the distribution of significant (positive or negative) associations with forest as compared with the analysis where there were no overlapping landscapes. In general, overlapping landscapes increased the variability around the forest coefficient for all species, but there was no shift in the sign of the forest coefficient for any species (Table 1.3).

Pitfall 3: Using only a portion of the potential range of the landscape predictor variable of interest

Reductions in the range of forest cover led to large changes in the forest coefficient for every species. For the gray treefrog and green frog, there was a switch from a statistically significant positive association with forest cover in the full dataset to statistically significant negative association with forest cover in two of the reduced range datasets. There was also a statistically significant negative association between the

leopard frog and forest in the full dataset, which switched to a significant positive association in the 40-60 % forest cover dataset. In addition to these switches in the signs of the forest coefficient, there were shifts from a significant association to no association for every species. There was a particularly strong positive association with forest cover in the 0-15% forest cover dataset for the gray treefrog. The lack of an association between forest cover and abundance for the spring peeper in the 50–100 % forest cover dataset was also striking. Variability around the mean forest coefficient was also generally much higher in the reduced range analyses than in the analyses based on the full range in forest cover (Table 1.4).

Pitfall 4: Failing to account for correlations among landscape predictor variables

High negative correlations between the amount of forest cover and the amount of development in the landscape inflated the positive association with forest cover for every species except the spring peeper. The effect of the correlation between development and forest cover was particularly pronounced for three species – the wood frog, leopard frog, and American toad. Controlling for development by including it in the multiple regression analysis in the ‘High Correlation’ dataset brought the results in the ‘High Correlation’ dataset more in line with the ‘Low Correlation’ dataset for the wood frog, leopard frog, and American toad, but less so for the spring peeper, gray treefrog and green frog. The results of the simple regression and multiple regression analyses in the ‘Low Correlation’ dataset were very similar (Table 1.5).

Pitfall 5: The existence of broad-scale spatial trends confounding landscape-scale effects

Controlling for broad-scale trends in the data using residuals from a multiple regression model with the X and Y co-ordinates reduced the strength of the association with forest cover for every species. This was particularly the case for the wood frog; a strong positive association with forest cover shifted to no association with forest cover in the residual regression model for this species (Table 1.6).

1.5 Discussion:

My results indicate that study design alone can lead to both shifts in the sign and to large decreases in the strength of the inferred relationship between a species response and a landscape predictor. The range of the predictor variable – forest cover in this dataset – had the largest effect on the sign of the relationship and on the strength of the inferred relationship. Correlations between forest and development also led to shifts in the sign of the forest coefficient for some species, and had a major effect on the strength of the inferred relationship for other all species. Broad-scale spatial trends in the data and overlapping landscapes also had major effects on the strength of the inferred relationship for some species, but did not lead to switches in the sign of the relationship. The scale at which the amount of forest was measured had the least impact of the five pitfalls, but still led to a switch in the sign of the relationship for one species – the green frog.

The most important finding of this chapter was the very strong effect that the range of the predictor variable (Pitfall 3) had on the inferred relationship between forest cover and anuran abundance. The main reason for this was the non-monotonic relationship between the amount of forest cover in the landscape and the abundance of

the wood frog, spring peeper, leopard frog, and gray treefrog and green frog (Fig. 2). These results are important for two reasons. First, the bell-shaped relationship with forest cover I found for the gray treefrog has not to my knowledge been previously reported in the literature. Secondly and more generally, very weak non-monotonic trends in the data for the wood frog, leopard frog and green frog (Fig. 2) were sufficient to cause shifts in the forest coefficient depending on the range of forest cover considered in the analysis. These results show that it is important to include sites from the full range of values of the predictor variable of interest even if there is no *a priori* expectation of a non-monotonic relationship. If including sites from the full range of values of the predictor variables is not possible (or not desired e.g. Herrmann et al (2005)), then the possible implications of the range of values used in the analysis should be discussed. Ideally, there should be an even sampling effort across the full range of each predictor variable as inadequately sampling the extremes of the predictor variable reduces the power of a study to detect their effects.

Correlations among predictor variables (Pitfall 4) can lead to shifts in the coefficient of the predictor of interest, as occurred for the leopard frog in this study. It is not surprising that when forest and development are negatively correlated, leopard frog abundance appears to be positively correlated with high forest cover, as the negative association of this species with traffic density and urbanization is stronger than its negative association with forest cover independent of development (Gagné and Fahrig 2007; Eigenbrod et al 2008a). Overall, however, even a high correlation with a predictor known to have a strong impact on the response (development) had a smaller effect on the

forest coefficient than only considering a portion of the range of the predictor of interest (previous paragraph).

My results also clearly illustrate how correlations among predictor variables can lead to large reductions in statistical power. For example, the wood frog – a forest obligate species (e.g. Porej et al 2004) showed only a weak negative effect of forest cover after controlling for the effect of development when the negative correlation between development and forest cover was high. Also of note was the switch in the sign of the association with forest cover of the gray treefrog after controlling for development from positive to negative when the correlation between forest and development was high. The latter result was probably due to the non-monotonic relationship between this species and forest cover discussed earlier, and illustrates how high correlations between predictor variables can decrease interpretability of results. The best approach (Brennan et al 2002) for dealing with naturally correlated predictor variables (landscape or otherwise) is to minimize correlations in the dataset through careful site selection (e.g. Guerry and Hunter 2002).

The reduction in the statistical power to detect a positive association with forest cover after controlling for broad-scale trends (Pitfall 5) was not surprising; forest cover was correlated with the Y (Pearson's $r = 0.64$) and X ($r = -0.433$) coordinates. However, it is interesting that the reduction in the forest coefficient for the wood frog was much greater than for the spring peeper, indicating that the variation explained by forest cover for the former was almost entirely variation shared with geographic location. This may be because the southern and western edge of this study is near the edge of the wood frog's range (IUCN et al 2006). It is thus impossible to know whether climatic factors (probably

correlated with the type of forest present) or the amount of forest in the landscape are driving wood frog abundance in my study. The spring peeper, on the other hand, continues to be present as far south as the Gulf of Mexico (IUCN et al 2006), and clearly shows a strong positive association with forest cover above and beyond broad-scale spatial trends. It is also possible that not considering broad-scale trends can lead to shifts in the sign of the forest coefficient. Lehtinen et al (1999) found a positive association between the presence of the American toad and forest cover in Minnesota. Their sites with low forest cover were all located in the tallgrass prairie ecoregion, while those with high forest cover were within the northern deciduous forest ecoregion. The American toad is common throughout the latter, but generally not found in the former (IUCN et al 2006). It is therefore possible that the positive association with 'forest cover' observed in Lehtinen et al (1999) is due to broad-scale geographic trends and not forest cover per se. Brennan et al (2002) suggest that the best way of controlling for broad-scale trends is to select study sites with high and low values of predictors of interest throughout the study region to avoid correlations (e.g. Carr and Fahrig 2001).

Overlapping landscapes (Pitfall 2) did not lead to shifts in the sign of the forest coefficient, but did lead to increased variation around the mean of the forest coefficient among subsets as compared to the subsets where there was no overlap. This is due to the reduced number of independent landscapes in the 'overlapping' analyses; there are effectively only as many independent landscapes per subsets as clusters of sites. Generally 5-10 clusters were required to attain 50 sites, so there were effectively only 5-10 landscapes (at the 10,000 m scale) in the 'overlapping' analyses as compared with the 50 landscapes in the non-overlapping analyses. This reduction in independent landscapes

translates into less variation in the amount of forest cover within a subset due to pseudoreplication of the landscapes. The reduction in independent landscapes also translates into greater variation in the distribution of forest cover among subsets as each subset is, on average, less representative of the whole dataset. It is, for example, less likely that the full range of the predictor of interest (Pitfall 2) is included in a subset where the 50 sites are only distributed over 5 landscapes, than where the sites are distributed over 50 independent landscapes.

The scale at which the amount of forest cover in the landscape was measured (Pitfall 1) caused a shift in the sign of the coefficient for the green frog, but otherwise caused only relatively minor shifts in the forest coefficient. The former result may be a consequence of small shifts in the average structure of the landscape between the 500 and 5000 m scale in this dataset, as the relationship between forest cover and this species was very weak. It is likely that the effect of scale on the forest coefficient would have been greater if I had been able to examine a larger range of scales in this study. For example, Holland et al (2004) showed shifts in the sign of the relationship between the abundance of a beetle and the amount of forest in the landscape when the latter was measured at the 20 to 2000 m scale, i.e., two orders of magnitude vs. one order of magnitude in my study. Unfortunately, I was only able to test for the effect of scale at the 500 to 5000 m scale as all anuran calling within hearing distance (approximately 500 m) of the survey site was used as the response (Mossman et al 1998), and selecting non-overlapping landscapes at the 10 000 m scale would have severely restricted site selection.

Based on my findings and the experimental design of the 13 studies in Table 1.1, it appears that the differences between results in Table 1.1 could be largely due to

limitations in sampling design. Correlations between forest and roads/development probably had the largest effect on the results in these 13 studies. This is because this pitfall was more common in these 13 studies than a limited range in the amount of forest cover in the landscape, though my results suggest that the latter generally has a larger effect than correlations when it does occur. Forest cover was highly correlated with development or roads in 3 of the 13 studies and probably correlated in a further 5. In contrast, low range in forest cover was an issue in 3 of the 13 studies. As discussed earlier, broad-scale trends in the data are likely to have affected the findings of Lehtinen et al. (1999).

Of course, the 13 studies differed in more than correlations between predictor variables, range of forest cover and broad-scale trends in the data. However, no other factors are as likely to lead to the observed differences in the forest coefficient as these. Sample size had relatively little effect on the results; in the 11 of the 13 studies examined here that measured the effect of forest for at least two species, there was no significant correlation between sample size and the ratio of significant to non-significant effects of forest cover ($n=11$; Spearman's $\rho = 0.24$, $p = 0.48$). Year-to-year differences in sampling may have affected the strength of associations between individual species and landscape-scale variables but seem unlikely to have led to systematic shifts in the forest coefficient. It is possible that regional differences in landscape context may have affected the forest coefficient, as suggested by Hecnar and M'Closkey (1998) and Knutson et al (1999). For example, in regions with high-intensity agriculture, anurans that usually prefer open landscapes may actually be more abundant in forests as these contain lower levels of agrochemicals (Houlahan and Findlay 2003). However, controlling for broad-

scale trends in my study – which encompasses a large range of agricultural intensity and several ecoregions – did not result in a shift in the sign of the forest coefficient for any species, suggesting that regional differences are also unlikely to lead to systematic shifts in the sign of the forest coefficient.

In light of my results and the above discussion, it seems likely that the majority vote in Table 1.1 gives the ‘true’ association with forest cover for each of the six species of anurans except the leopard frog and gray treefrog. For the former, it is likely that negative correlations between forest cover and development or roads artificially weakened the negative association with forest cover observed for this species. A lack of studies looking at non-monotonic relationships between forest cover and gray treefrog abundance is almost certainly the main reason for the contradictory results in Table 1.1 for this species.

The results of my study have important management implications. Misidentification of the true direction of the relationship between a landscape predictor and a response will lead to incorrect management actions. Even studies that show no significant effect of a biologically important predictor variable due to issues in sampling design can have implications for conservation, as they can be taken by policy makers as evidence that a given predictor is irrelevant. Poorly designed studies that find no effect of a predictor can thus serve as justification for not initiating important management actions. Proper study design is arguably most important for poorly-studied species, as there will be little *a priori* knowledge to aid the interpretation of results. However, common problems in landscape ecology, such as correlations among predictors, mean that even the most widely reported finding from well-studied species or phenomena, such as the

relationship between habitat fragmentation and wildlife populations (Fahrig 2003), may be incorrect. Clearly, in many situations it will not be possible to conduct 'ideal' landscape-scale studies as suggested by Brennan et al (2002). However, this study illustrates that it is vital for investigators to carefully consider the issues discussed by Brennan et al, and to discuss the implications of any shortcomings in study design (e.g. Houlahan and Findlay (2003)).

Table 1.1 Summary of the results of 13 studies examining the effects of the amount of forest cover in surrounding landscapes on the presence or abundance of six anuran species in focal ponds/wetlands in the centre of each landscape.

Species	Summary of forest effects		
	Positive	Negative	No effect
<i>Rana sylvatica</i> (Wood Frog) ¹	8	0	3
<i>Pseudacris crucifer</i> (Spring Peeper) ²	8	0	1
<i>Rana pipiens</i> (Northern Leopard Frog) ³	0	3	6
<i>Bufo americanus</i> (American Toad) ⁴	2	5	4
<i>Hyla versicolor</i> (Gray Treefrog) ⁵	3	1	7
<i>Rana clamitans</i> (Green Frog) ⁶	3	0	4

^{1,3,4,5}Lehtinen et al 1999; ^{1,3,4,5,6}Findlay et al 2001; ^{1,2,3,4,6}Guerry and Hunter 2002; ^{1,2,3,4,5,6}Houlahan and Findlay 2003; ^{1,2,3,4,5,6}Trenham et al 2003; ¹Homan et al 2004; ^{2,4,5}Knutson et al 2004; ^{2,4,5,6}Price et al 2004; ¹Porej et al 2004; ^{1,2,3,4}Gibbs et al 2005; ^{1,2,4,5,6}Herrmann et al 2005; ^{1,2,3,4,5,6}Gagné and Fahrig 2007; ^{1,2,3,4,5,6}Eigenbrod et al 2008

Table 1.2 Effect of the scale at which forest cover was measured on the forest

coefficient. 1000 random subsets (each with $n = 50$) were selected from the full dataset, and anuran abundance was regressed on forest cover at each of the four scales.

Significance is at $\alpha = 0.05$.

Species	Scale (m)	Mean forest coefficient $\pm$ 1 SD	Number of positive forest coefficients	Number of significant positive associations with forest	Number of significant negative associations with forest
Wood Frog	500	0.64 $\pm$ 0.376	959	355	0
	1000	0.72 $\pm$ 0.386	967	400	0
	3000	0.88 $\pm$ 0.402	980	520	0
	5000	0.99 $\pm$ 0.422	988	590	0
Spring Peeper	500	1.12 $\pm$ 0.508	982	504	1
	1000	1.39 $\pm$ 0.517	996	681	1
	3000	1.75 $\pm$ 0.524	999	853	0
	5000	1.91 $\pm$ 0.548	1000	892	0
Leopard Frog	500	-0.30 $\pm$ 0.208	74	0	160
	1000	-0.32 $\pm$ 0.218	70	0	182
	3000	-0.29 $\pm$ 0.238	119	2	136
	5000	-0.23 $\pm$ 0.247	164	3	78
American Toad	500	-0.58 $\pm$ 0.330	41	0	294
	1000	-0.59 $\pm$ 0.361	50	0	283
	3000	-0.50 $\pm$ 0.384	93	1	175
	5000	-0.46 $\pm$ 0.397	109	1	140
Gray Treefrog	500	0.27 $\pm$ 0.498	704	43	3
	1000	0.35 $\pm$ 0.514	751	50	2
	3000	0.42 $\pm$ 0.532	781	62	0
	5000	0.47 $\pm$ 0.558	806	64	1
Green Frog	500	-0.07 $\pm$ 0.383	431	6	33
	1000	-0.01 $\pm$ 0.404	490	13	21
	3000	0.12 $\pm$ 0.434	614	31	12
	5000	0.18 $\pm$ 0.455	660	44	9

Table 1.3 Comparison of results of simple linear regression analyses from two sets of analyses – ‘Overlapping landscapes’, and ‘No overlap at the 5000 m scale’ (see methods for details). Anuran abundance was regressed on forest cover at the 5000 m scale for all analyses. + indicates that there were at least 25 significant ($\alpha = 0.05$) positive associations with forest cover for an analysis; ++ indicates at least 250 significant positive associations, and +++ at least 500 significant positive associations with forest cover. –, --, --- indicates at least 25, 250 or 500 significant negative associations, respectively. NF (no effect) indicates that there were less than 25 significant positive or negative associations per analysis.

Species	Overlapping Landscapes		No Overlap at 5000 m Scale	
	Mean forest coefficient $\pm$ 1 SD	Sign of forest coefficient	Mean forest coefficient $\pm$ 1 SD	Sign of forest coefficient
Wood Frog	0.54 $\pm$ 1.351	+	0.99 $\pm$ 0.422	+++
Spring Peeper	2.52 $\pm$ 1.666	++	1.91 $\pm$ 0.548	+++
Leopard Frog	-1.43 $\pm$ 1.217	--	-0.23 $\pm$ 0.247	-
American Toad	-1.05 $\pm$ 1.401	-	-0.46 $\pm$ 0.397	-
Gray Treefrog	1.80 $\pm$ 1.838	+	0.47 $\pm$ 0.558	+
Green Frog	0.39 $\pm$ 1.198	NF	0.18 $\pm$ 0.455	+

Table 1.4 Comparison of results of simple linear regression analyses with forest as the predictor from with five different ranges in the percentage of forest cover in the landscape at the 5000 m scale. 1000 random subsets (each with $n = 25$) were selected from each dataset, and anuran abundance was regressed on forest cover at the 5000 m scale. + indicates that there were at least 25 significant ($\alpha = 0.05$) positive associations with forest cover for an analysis; ++ indicates at least 250 significant positive associations, and +++ at least 500 significant positive associations with forest cover. -, --, --- indicates at least 25, 250 or 500 significant negative associations, respectively. NF (no effect) indicates that there were less than 25 significant positive or negative associations per analysis.

Species	Range in forest cover (%)					Sign of forest coefficient				
	0-15	40-60	30-70	50-100	0-100	0-15	40-60	30-70	50-100	0-100
	Mean forest coefficient ± 1 SD									
Wood Frog	-0.69 $\pm$ 2.270	1.15 $\pm$ 1.938	0.15 $\pm$ 1.148	1.18 $\pm$ 1.190	0.97 $\pm$ 0.647	NF	+	NF	+	++
Spring Peeper	13.33 $\pm$ 4.536	1.29 $\pm$ 1.722	0.64 $\pm$ 1.233	0.32 $\pm$ 0.816	1.94 $\pm$ 0.859	+++	+	+	NF	+++
Leopard Frog	-0.80 $\pm$ 2.105	1.05 $\pm$ 1.198	-0.25 $\pm$ 0.618	-0.69 $\pm$ 0.639	-0.23 $\pm$ 0.385	NF	+	-	-	-
American Toad	-2.60 $\pm$ 3.082	-0.45 $\pm$ 1.854	0.17 $\pm$ 0.945	-0.43 $\pm$ 1.052	-0.47 $\pm$ 0.598	-	NF	NF	NF	-
Gray Treefrog	10.40 $\pm$ 3.814	-0.80 $\pm$ 2.679	-0.66 $\pm$ 1.404	-0.24 $\pm$ 1.457	0.50 $\pm$ 0.968	+++	-	-	NF	+
Green Frog	-1.83 $\pm$ 3.380	-0.29 $\pm$ 2.201	0.57 $\pm$ 1.213	-0.08 $\pm$ 1.214	0.20 $\pm$ 0.710	-	NF	+	NF	+

Table 1.5 Comparison of results of analyses from two datasets with high and low correlations, respectively, between development and forest at the 5000 m scale. Anuran abundance was regressed on forest cover for the 'Simple linear' models, and on development and forest cover in the 'Devel. + forest' models. + indicates that there were at least 25 significant ($\alpha = 0.05$) positive associations with forest cover for an analysis; ++ indicates at least 250 significant positive associations, and +++ at least 500 significant positive associations with forest cover. -, --, --- indicates at least 25, 250 or 500 significant negative associations, respectively. NF (no effect) indicates that there were less than 25 significant positive or negative associations per analysis.

Species	-----High correlation dataset-----					-----Low correlation dataset-----				
	Mean forest		Sign of forest		coefficient	Mean forest		Sign of forest		coefficient
	coefficient $\pm$ 1 SD	Devel.	Simple	Linear		coefficient $\pm$ 1 SD	Devel.	Simple	Linear	
	Model	+ forest	Model	Model		Model	+ forest	Model	Model	+ forest
Wood Frog	1.14 $\pm$ 0.317	0.68 $\pm$ 0.478	+++	+		0.56 $\pm$ 0.519	0.57 $\pm$ 0.523	+	+	+
Spring Peeper	1.73 $\pm$ 0.411	0.79 $\pm$ 0.621	+++	+		2.27 $\pm$ 0.625	2.27 $\pm$ 0.627	+++	+++	+++
Leopard Frog	0.12 $\pm$ 0.157	-0.22 $\pm$ 0.230	+	-		-0.62 $\pm$ 0.325	-0.63 $\pm$ 0.324	--	--	--
American Toad	-0.08 $\pm$ 0.293	-0.42 $\pm$ 0.445	NF	-		-1.03 $\pm$ 0.463	-1.05 $\pm$ 0.457	--	--	--
Gray Treefrog	0.65 $\pm$ 0.457	-0.29 $\pm$ 0.678	+	-		0.29 $\pm$ 0.666	0.29 $\pm$ 0.669	+	+	+
Green Frog	0.55 $\pm$ 0.353	0.48 $\pm$ 0.487	+	+		-0.16 $\pm$ 0.547	-0.17 $\pm$ 0.538	-	-	-

Table 1.6 Effect of controlling for broad scale trends in the data on the forest coefficient.

1000 random subsets (each with $n = 50$) were selected from the full dataset. In the 'Forest Model' anuran abundance was regressed on forest cover at the 5000 m scale. In the 'Residual Model' anuran abundance was first regressed on the X and Y co-ordinates and their product. The residuals from this first regression were then regressed on forest cover at the 5000 m scale. + indicates that there were at least 25 significant ($\alpha = 0.05$) positive associations with forest cover for an analysis; ++ indicates at least 250 significant positive associations, and +++ at least 500 significant positive associations with forest cover. -, --, --- indicates at least 25, 250 or 500 significant negative associations, respectively. NF (no effect) indicates that there were less than 25 significant positive or negative associations per analysis.

Species	Residual Model		Forest Model	
	Mean forest coefficient $\pm$ 1 SD	Sign of forest coefficient	Mean forest coefficient $\pm$ 1 SD	Sign of forest coefficient
Wood Frog	0.11 $\pm$ 0.303	NF	0.99 $\pm$ 0.422	+++
Spring Peeper	1.17 $\pm$ 0.479	++	1.91 $\pm$ 0.548	+++
Leopard Frog	-0.22 $\pm$ 0.194	-	-0.23 $\pm$ 0.247	-
American Toad	-0.54 $\pm$ 0.321	-	-0.46 $\pm$ 0.397	-
Gray Treefrog	0.29 $\pm$ 0.417	NF	0.47 $\pm$ 0.558	+
Green Frog	0.04 $\pm$ 0.327	NF	0.18 $\pm$ 0.455	+

Fig. 1.1 Location of 1141 surveys sites (▲) within Wisconsin (600 sites) and Michigan (541 sites), USA. Sites are clustered by survey route.

Fig. 1.2 Relationships between anuran relative abundance at 1141 sites (ponds/wetlands) and the percentage forest cover in the surrounding landscape measured at the 5000 m scale (radius). The lowess smoothing line is shown for each species.

CHAPTER 2: THE RELATIVE EFFECTS OF ROAD TRAFFIC AND FOREST COVER ON ANURAN POPULATIONS

(Adapted from Eigenbrod F, Hecnar SJ, Fahrig L (2008) The relative effects of road traffic and forest cover on anuran populations. *Biological Conservation* 141:35-46)

2.1 Chapter summary: 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 as 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, I 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 to 2000 m of the edge of each pond. I 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 $R^2 = 0.34$; $P < .0001$) 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. My 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 among species.

2.2 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. My 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 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 is important for long-term population persistence (deMaynadier and Hunter 1999). Indeed, forest cover within a landscape extending 100 to 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 to re-colonize 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); between anuran pond occupancy and road density (Vos and Chardon 1998); and between 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; Lehtinen et al 1999; Knutson 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.

My purpose was to quantify the relative importance of the full effects of deforestation and roads on anuran populations. I 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.

2.3 Methods:

Description of Study Area

I conducted the fieldwork for this chapter in rural areas of eastern Ontario and western Quebec within 100 km of Ottawa, Ontario, Canada (45°42'N, 75°71'W) in the spring and summer of 2005 and 2006. This region is located in the Great-Lakes St-Lawrence ecoregion, and has a continental climate characterized by cold winters and hot, humid summers. Prior to European settlement, the region was covered by deciduous and coniferous forests and wetlands. The dominant tree species are the sugar maple (*Acer saccharum*), yellow birch (*Betula lutea*), hemlock (*Tsuga canadensis*) and white pine (*Pinus strobus*). Swampy forests are also common (dominated by the silver maple (*Acer saccharinum*), cedar (*Thuja occidentalis*), dogwood (*Cornus* spp.), willows (*Salix* spp.), alder (*Alnus rugosa*) and ash (*Fraxinus* spp.) (Houlahan and Findlay 2003). Only 60-70% of southeastern Ontario remains forested, with mixed agriculture the dominant land non-forest land use. Wetlands have been particularly negatively affected by development in the region, decreasing from 45.8% of the area near Ottawa in 1890 to 12.6 % in 1980 (Snell 1987 in Houlahan and Findlay (2003)). The region is bisected by three major four lane divided intercity highways - Highway 401 (which connects Toronto and Montreal), Highway 417 (connecting Ottawa and Montreal), and Highway 416 (connecting Ottawa and Highway 401), as well as numerous two-lane highways with intermediate traffic volumes and a large number of paved and unpaved county and local roads.

Study Design

I surveyed 36 permanent ponds in 2005 and a 23 pond subset of these in 2006 (Fig. 2.1). Ponds were at the centre of 1500 m radius landscapes with varying amounts of forest cover and traffic density. 1500 m 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, I selected ponds in four landscape types: low forest/low traffic, low forest/high traffic, high forest/low traffic, and high forest/high traffic (Fig. 2.2). 'Low forest' landscapes had $\leq 35\%$ forest cover and 'high-forest' landscapes had $\geq 60\%$ 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 freeway within 1500 m of the pond (Table 2.1).

Anuran Field Surveys

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

In 2005 I 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. I surveyed each pond for 5 minutes, 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 ≥ 15 individuals calling, calls overlapping. I included calling from within 100 m of the pond to account for the preference of several species (wood frog, spring peeper, gray treefrog), to breed in ephemeral vernal pools - which were very common in the forests adjacent to my sampling ponds - in addition to permanent ponds (Skelly et al 1999). The ponds were divided into nine survey routes, and were surveyed over four nights that were as close to consecutive as weather conditions permitted. Surveys were only conducted on warm evenings (average survey temperature April-mid-May $8.3^{\circ}\text{C} \pm 3.3$ SD; mid-May to mid-June $16.0^{\circ}\text{C} \pm 5.6$ SD; July $22.2^{\circ}\text{C} \pm 2.6$ SD) with little wind (average Beaufort wind scale reading 0.93 ± 1.14 SD). The order in which the routes were done within a survey was randomized, and the order in which ponds were surveyed within a route was alternated among forwards, backwards, starting at the middle of the route and moving forwards, and starting at the middle and moving backwards, to vary the survey time for each pond. One pond was only surveyed seven times due to lack of access for the last survey. In 2006, I conducted eight chorus surveys of the 23 pond subset. The only difference in the protocols between 2005 and 2006 was that I divided the ponds into six routes in 2006, rather than the nine routes I used in 2005. One pond was only surveyed seven times in 2006.

I conducted the visual surveys between May 3 and June 12, 2005 to correspond with the peak breeding season of leopard frogs and green frogs (Carr and Fahrig 2001). While I recorded all anurans seen during the surveys, I focused on green frogs and leopard frogs as visual surveys produce better relative abundance estimates for green frogs than call surveys (Nelson and Graves 2004), and leopard frog presence may be underestimated from call surveys alone (de Solla et al 2005). Each survey was conducted between 0900 and 1800 h over four days. Adult and juvenile frogs were counted as a surveyor slowly walked along the pond edge or through shallow emergent vegetation. The time spent at each pond varied from 9 to 108 minutes, with more time spent at ponds with greater perimeter and higher amounts and densities of emergent vegetation. I did not do visual surveys in 2006 due to logistic constraints.

Landscape and Local Variables

I quantified three landscape variables - percent forest, percent wetland, and traffic density - in nested landscapes of 100 to 2000 m radii from the edge of the sampling ponds at 100 m intervals. I obtained forest and wetland cover in the landscapes from digital 1:50 000 Natural Resources Canada topographic maps; wetland cover was included to control for its effect on anuran populations (e.g. Vos and Chardon 1998; Findlay et al 2001). I obtained digital maps of all public roads from the National Road Network of Canada vector road datasets for Ontario and Quebec (Natural Resources Canada 2003). I obtained traffic volumes, measured as average annual daily (24-hour) traffic (AADT), for most roads from the City of Ottawa transportation department, the City of Gatineau transportation department, the Regional Municipality of Ottawa-

Carleton transportation department, township and county public works departments, and the Ontario and Quebec Ministries of Transportation. However, for some roads AADT counts did not exist. When these roads were minor, I estimated 250 AADT for two-lane gravel roads, 25 for one-lane gravel roads, 500 for paved roads, and 50 for dead-end roads (paved or gravel), based on AADT counts for similar roads in the study area. I also did traffic counts for seven mid-sized (paved, two-lane, centre-line) roads for two 15 minute periods on consecutive weeknights between 1900 and 2130 h. These counts were immediately preceded or followed by 15 minute traffic counts on roads with known AADT counts. I then estimated AADT for the roads with unknown traffic volumes by assuming the same ratio of the 15 minute count to AADT as for the roads with known AADT. The values for the two nights were averaged. I calculated traffic density ($\sum \text{AADTm/m}^2$) in each landscape as the length of each road in the landscape multiplied by its traffic volume, summed over all the road segments in the landscape, divided by the landscape area (Carr and Fahrig 2001). GIS analyses were done using ArcGIS 9.0 (Environmental Systems Research Institute, Redlands, California, USA).

I quantified 6 local pond variables to control for their effects in the statistical models: average conductivity, average pH, pond perimeter, percent cover of emergent and floating vegetation within 2 m of the pond edge (all measured in spring/summer 2005), amount of overhanging vegetation and degree of insolation (sun exposure) (measured in 2006). Conductivity and pH, which can significantly affect anurans (e.g. Weyrauch and Grubb 2004; Babbitt et al 2006), were measured at four points at each pond. Pond perimeter, which is positively correlated with species richness (Hecnar and M'Closkey 1998), was measured using a handheld GPS unit with sub-meter resolution

(Trimble GeoExplorer, Trimble Navigation Ltd, Westminster, Colorado USA).

Overhanging vegetation may provide calling sites for treefrogs, and also affects sunlight amount at a pond, which, together with the amount of emergent and floating vegetation near the pond edge has been shown to affect leopard and green frog abundances (Pope et al 2000; Carr and Fahrig 2001). These variables were measured with systematic surveys using line transects perpendicular to the pond edge at evenly spaced intervals (19, 38, 56 or 76 m) using a modification of the protocol of Gagné and Fahrig (2007). Between 4 and 16 transects were taken at each pond, depending on pond size, and incorporating all habitat types at the pond edge. At each transect I recorded whether or not there were trees overhanging the pond edge, degree of insolation within 2 m of the pond edge (full sun all day, shaded part of the day, shaded all day), emergent vegetation and surface vegetation percent cover at 1 m and 2 m from the pond's edge. I averaged the values for each variable over all transects at each pond.

Statistical analysis

Chorus surveys are a good relative abundance indicator for many anuran species (Shirose et al 1997; Stevens and Paszkowski 2004). I used summed chorus counts as the response variable for all species except leopard frogs and green frogs (reasons below). Summed chorus counts give weight to ponds with both consistent calling and high numbers of calling individuals (Pope et al 2000). However, de Solla et al (2005) showed that chorus surveys alone can underestimate leopard frog presence. Thus, in 2005 for leopard frogs, I used summed chorus counts, but if no leopard frogs were heard calling but at least one individual was seen during a day survey, I recorded a count of one rather

than zero, to indicate a small breeding population. Since visual surveys have been shown to provide better green frog population estimates than chorus surveys (Nelson and Graves 2004) and this species is very conspicuous in visual surveys (Hecnar and M'Closkey 1997a), I used the maximum number of adults seen at a pond during the visual surveys as the response for this species in 2005. Only six anuran species were sufficiently common for species-level analyses. Species richness was defined as the total number of anuran species seen or heard during all surveys at each pond in 2005, and the total number of anuran species heard during call surveys at each pond in 2006.

I used generalized linear models (GLMs) to determine the relative effects of traffic density and forest amount on species richness and relative abundances of individual species. I used the *glm* function in R 2.2 (R Development Core Team 2005), and the *glm.nb* function in the *MASS* package (Venables and Ripley 2002) in R 2.2. I used a Gaussian, Poisson or negative binomial link function depending on the response distribution of each species. Model assumptions were checked by examining the model deviance residuals as well as the partial residual plots for significant and borderline significant predictors. The green frog numbers were log-transformed to fit the normality assumption of the Gaussian model.

Statistical models were built for species richness and for each species at each of the 20 spatial scales. Each model included traffic density, percent forest and percent wetland as predictors. In addition, the statistical models for each species included any local pond variable that was significant at $\alpha = 0.05$ in the last step of a stepwise multiple regression with all local variables (Table 2.2). I used the *stepAIC* function in *MASS* for the stepwise regression. I compared the relative effects of traffic and forest by comparing

the deviance explained by each term after controlling for the effects of all other predictors. The significance ($\alpha = .05$) of the explained deviance was tested using a chi-square test for the Poisson and negative binomial models, and an F-test for the Gaussian models with the *Anova* function in the *car* package in R 2.2 (Fox 2006). I also calculated the percentage of deviance explained by traffic and forest (the explained deviance of the term divided by the null deviance of the model (Crawley 1993)) as an estimate of the predictor's explanatory power.

I built statistical models as described above using just the 2005 data. I then ran the same models using the 2006 data to ensure that the patterns I found in 2005 were not simply a statistical artifact of the year in which sampling occurred.

I checked for the presence of spatial autocorrelation in the residuals of my statistical models by calculating Moran's *I* for all distance classes in spatial correlograms (Diniz-Filho et al 2003). I created correlograms from the model (2005 data) for each species and for species richness at the scale at which the effect of traffic or forest (whichever was higher) was highest. I also created a correlogram for the wood frog from the 2006 data, as the abundance data for this species was judged to be more reliable in 2005 than 2006 for this species (Fred Schueler, personal communication). I considered significant spatial autocorrelation to be present if at least one of the coefficients was significant at α/K , where K is the number of distance classes, and used Sturge's rule for determining the optimal number of distance classes (Legendre & Legendre 1998). Spatial autocorrelation of the residuals of a statistical model invalidates the important assumption of most statistical tests that residuals are independent of each other. Positive spatial autocorrelation (which is very common in ecological datasets) can lead to

underestimation of the confidence intervals, and thus inflation of Type I errors (Legendre 1993).

2.3 Results:

All nine anuran species in the regional species pool were present at my sites. Occurrence frequencies are given in Table 2.3. Species richness ranged from 3 to 7 species per pond in 2005 (average 5.1 ± 1.19 SD) and from 2 to 6 species in 2006 (average 4.6 ± 1.19 SD). The range of the percentage of forest and traffic density in the landscape at all spatial scales was 1 – 99% and $0.1 - 21.5 \sum \text{AADTm/m}^2$ respectively, and the correlation between them was less than ± 0.20 at all scales (Table 2.4).

The association between species richness and traffic density was more than three times the association between species richness and forest cover in the landscape (Fig. 2.3). Statistical models were built for six individual species (wood frog, spring peeper, leopard frog, American toad, gray treefrog and green frog). For American toad, leopard frog and gray treefrog, relative abundance was more strongly associated with traffic density than with percentage of forest in the landscape (Fig. 2.3). Green frog relative abundance was approximately equally associated with traffic density and forest cover. Spring peeper and wood frog abundances were much more strongly associated with forest cover than with traffic density (Fig. 2.3).

In 2005, I found significant negative associations between traffic density and species richness ($P = 0.0003$, partial $R^2 = 0.34$ at the 500 m scale), and the relative abundances of American toads ($P = 0.024$, 12.3% deviance explained at the 500 m scale) and leopard frogs ($P = 0.03$, 7% deviance explained at the 2000 m scale). There were

borderline significant negative associations between traffic density and relative abundances of green frogs ($P = 0.058$, partial $R^2 = 0.11$ at the 300 m scale), wood frogs ($P = 0.067$, 7% deviance explained at the 2000 m scale), and gray treefrogs ($P = 0.097$, 5% deviance explained at the 200 m scale). There were significant positive associations between forest cover and relative abundances of spring peepers ($P = 0.0006$, partial $R^2 = 0.33$ at the 100 m scale) and wood frogs ($P = 0.018$, 12% deviance explained at the 100 m scale). Species richness ($P = 0.075$, partial $R^2 = 0.10$ at the 500 m scale), and green frog abundance ($P = 0.09$, partial $R^2 = 0.08$ at the 400 m scale) showed borderline significant positive associations with forest cover. I observed a borderline significant negative association between leopard frog relative abundance and forest cover ($P = 0.054$, 6% deviance explained at the 1500 m scale) (Fig. 2.3). The abundances of all six common species were negatively correlated with traffic in 2005, but both positive and negative relationships between species abundances and forest cover in the landscape were present (Fig. 2.4). No significant (α/K , where $\alpha = 0.05$ and $K = 11$) spatial autocorrelation was present in the residuals of any analyses with the exception of the wood frog in 2005.

Results from 2006 (Fig. 2.5) were generally consistent with those from 2005 (Fig. 2.3), with no change in the relative effects of traffic and forest for any species or for species richness between years. However, wood frogs showed a much stronger positive association with forest cover in 2006 (56% of deviance explained at the 100 m scale) than in 2005 (12% of deviance explained at the 100 m scale). Wood frogs also showed a significant positive association with traffic in 2006 (maximum significance of association $P = 0.017$ and 15% of deviance explained at the 100 m scale), while showing a (non-significant) negative association with traffic at all scales in 2005. In addition, leopard

frogs were not significantly associated with traffic density in 2006, unlike in 2005.

Finally, American toad abundance was significantly negatively associated with forest cover in 2006 (maximum significance of association $P = 0.037$ and 13% of deviance explained at the 100 m scale) but not in 2005.

2.4 Discussion:

This is the first study to evaluate the relative importance of road traffic and forest cover on amphibian species richness and abundance. I found that the negative effect of traffic on anuran populations in eastern Ontario is at least as large as the effect of forest cover in the landscape. I expect that similar patterns would be found throughout eastern Canada and the northeastern United States. My findings confirm the suggestions of Houlahan and Findlay (2003) and Cushman (2006) that the detrimental effect of roads on amphibians can be as severe as the effect of deforestation, and strengthen the case (Fahrig et al 1995; Vos and Chardon 1998; Hels and Buchwald 2001) that landscapes with low traffic are required for anuran conservation. However, my results also show that the relative importance of traffic density and forest cover varies enormously among species. Traffic density generally had a larger impact than forest cover on the relative abundances of species with weak or negative affinities with forest cover in the landscape, while for the two forest specialist species, the positive association between forest cover and relative abundance was much stronger than the negative association with traffic density.

A major and somewhat unexpected finding was that the negative association between anuran species richness and traffic density was much larger than the positive association between species richness and forest cover. Generally, positive associations

between species richness and forest cover are at least as large as negative associations with road density (Hecnar and M'Closkey 1998; Findlay et al 2001; Houlahan and Findlay 2003). Lehtinen et al (1999) do show that road density is the best predictor of species richness in Minnesota, but many of the landscapes in this study had high amounts of urbanization, which is usually correlated with paved road density. It is likely that the very strong impact of roads on species richness I observed is because I used traffic density, a more precise measure of road effects on anurans than road density (Fahrig et al 1995).

The weak positive association of species richness with forest cover (also found by Knutson et al 2004) was due to different species showing positive and negative associations with forest cover (Gagné and Fahrig 2007). In most studies forest cover in the landscape has a strong positive association with amphibian species richness (Hecnar and M'Closkey 1998; Kolozsvary and Swihart 1999; Lehtinen et al 1999; Findlay et al 2001; Houlahan and Findlay 2003; Herrmann et al 2005). Some of these relationships may be partly due to correlations between forest cover and roads or traffic (Houlahan and Findlay 2003; Chapter 1). Differences in the observed effects of forest cover on species richness may also be due to variations in forest configuration in the landscape (Guerry and Hunter 2002), or regional differences in forest cover between studies (Hecnar and M'Closkey 1998).

Most species showed the highest associations with forest cover and/or traffic within 500 m of the breeding ponds, indicating that this is the scale at which most anurans in the study area interact with the landscape surrounding breeding pools. This is similar to the 750 m scale of effect found by Vos and Chardon (1998) and Findlay et al

(2001), but less than the 2-3 km scale observed by Houlahan and Findlay (2003) and Price et al (2004). However, I found that the association between traffic density and leopard frog abundance peaked at the 2 km scale, which is similar to the findings of Carr and Fahrig (2001).

American toads and leopard frogs, the two species which were significantly negatively associated with traffic density in this study, also showed weak negative associations with forest cover in the landscape. Both toads and leopard frogs are known to be vagile, dispersing up to 5-6 km (Hamilton 1934; Seburn and Seburn 1998). Toads commonly use landscapes up to 1 km from breeding ponds (Forester et al 2006), while leopard frogs are thought to routinely move up to 8 km during yearly migrations (Seburn and Seburn 1998). It is thus not surprising that both species are vulnerable to high traffic densities in the landscape, and indeed other studies found that the related European toad *Bufo bufo* is vulnerable to traffic mortality (e.g. Van Gelder 1973; Schlupp and Podloucky 1994) and that leopard frogs are negatively affected by traffic density in the landscape (Carr and Fahrig, 2001). While both toads and leopard frogs have been shown to have a negative affinity with forest cover (Guerry and Hunter 2002; Gagné and Fahrig 2007; Chapter 1), positive associations with forest cover also exist for both (Gibbs et al 2005; Houlahan and Findlay 2003), so the weak negative associations I saw in this study with forest cover for these two species are not surprising.

Although I did not find a significant association between green frog or gray treefrog abundances and traffic density, there is probably a biologically significant negative effect of very high traffic densities on these species, which would have been apparent if I had had more ponds in landscapes with very high traffic densities (see Fig.

2.4(b)). This suggests that high-traffic roads can have negative effects on species that are relatively unaffected by moderate traffic densities, as both green frogs and gray treefrogs are known to be largely unaffected by paved road densities in the landscape (Trenham et al 2003; Weyrauch and Grubb, 2004) (but see Houlahan and Findlay 2003). However, Carr and Fahrig (2001) found that traffic had no significant effect on green frog populations; again it is possible that traffic densities were not sufficiently high in this study to demonstrate a negative effect. The lack of a significant association between the abundance of these two species and forest cover is supported by the literature (Trenham et al 2003; Hermann et al 2005; Gagné and Fahrig 2007; Chapter 1), though positive associations with forest cover also exist for both species (e.g. Houlahan and Findlay 2003). I did not have a sufficiently large sample size of sites with intermediate forest cover to test for the quadratic relationship between forest cover and gray treefrog abundance I observed in Chapter 1 (Fig. 2.5(c)).

The strong positive association between the abundance of spring peepers and wood frogs and forest cover in the landscape, and the lack of a significant association with traffic density in the landscape, are both supported by the literature. Both species have strong positive associations with forest cover (Gibbs 1998; Hecnar and M'Closkey 1998; Houlahan and Findlay 2003; Regosin et al 2003; Homan et al 2004; Porej et al 2004), while only two studies (Findlay et al 2001; Houlahan and Findlay 2003) indicate significant negative associations with traffic for these species. I am unable to explain the significant positive relationship between traffic density and wood frog abundance in 2006. A previously published positive association between paved road density and wood frog occupancy (Trenham et al 2003) suggests that my result is not a statistical artifact,

and that some feature associated with high-traffic roads (perhaps roadside ditches) has a positive effect on wood frog abundance.

I am confident that I correctly identified the relative importance of the effects of traffic density and forest cover on anuran species richness and relative abundances, as there was no change in relative effects from 2005 to 2006. However, wood frogs, leopard frogs, and American toads all showed between-year differences in the magnitude of their associations with traffic and/or forest cover. The 2006 results for wood frogs are more accurate than the 2005 results, because the early spring of 2005 was characterized by large temperature fluctuations resulting in unusually erratic and localized peaks in wood frog breeding and calling activity (Fred Schueler, pers. comm.). In addition, the residuals from the 2005 results for the wood frog showed spatial autocorrelation of the residuals; this was not a problem in 2006. The lack of an association between leopard frog abundance and traffic density in 2006 was surprising, as in addition to the significant negative association with traffic density I observed in 2005, Carr and Fahrig (2001) also showed a negative association for this species. Leopard frogs were more abundant in 2006 than in 2005, indicating that this species may establish populations in high-traffic landscapes during peak years, which are then unable to persist due to the high traffic. I have no explanation for why I observed a significant negative association between American toads and forests in 2006, but not in 2005.

Predatory fish negatively affect many anurans (Hecnar and M'Closkey 1997b; Smith et al 1999), and as I was unable to control for their presence, it is possible that this may have confounded my results. I compensated for this by including all calling from within 100 m of the pond edge, as fish-free vernal pools and wetlands were nearly

ubiquitous in the forests near my ponds. Vernal pools provide important breeding habitat for the anurans in my study region that are also the most negatively affected by predatory fish - wood frogs, spring peepers, and gray treefrogs (Hecnar and M'Closkey 1997b; Skelly et al 1999). It is, however, possible that the relatively weak relationship I observed between traffic density and leopard frog abundance as compared to Carr and Fahrig (2001) is due to a correlation between traffic density and fish presence, as the latter study was conducted entirely in fish-free ponds and leopard frogs rarely use vernal pools as breeding sites.

This study has important implications for conservation. My results show that landscapes with low traffic densities – especially within 500 m of breeding ponds – are vital for anuran conservation in eastern Ontario. Landscapes with high forest cover within 100 m of breeding ponds are also crucial for wood frog and spring peeper population maintenance, and even heavily forested landscapes with moderate traffic densities should have some conservation value for the maintenance of these forest obligate species. However, the conservation value of landscapes with low forest cover will be greatly reduced if traffic densities are high within 2000 m of breeding ponds, as the species particularly associated with open habitats – American toads and leopard frogs – are also the most vulnerable to road traffic. In conclusion, I agree with Gagné and Fahrig (2007) that a mosaic of high and low forest landscapes surrounding wetlands is needed for anuran conservation, but add that land managers should ensure that at least some ponds and wetlands are away from high-traffic roads for the maintenance of high regional anuran diversity.

Table 2.1 Percent forest cover and traffic density ($\Sigma \text{AADTm/m}^2$) within 1500 m radius of the edge of all surveyed breeding ponds (n = 36).

Sites	Percent Forest	Traffic Density	Sites	Percent Forest	Traffic Density
High forest, high traffic			Low forest, low traffic		
1	80	13.87	1	9	2.31
2	60	11.78	2	22	1.16
3	90	7.80	3	5	0.78
4	76	7.42	4	2	0.73
5	74	7.06	5	3	0.69
6	90	6.28	6	13	0.64
7	88	6.05	7	13	0.59
8	65	5.27	8	4	0.35
9	76	4.74	9	8	0.10
10	79	4.07	10	2	0.01
High forest, low traffic			Low forest, high traffic		
1	75	2.35	1	11	12.08
2	89	1.49	2	19	9.39
3	72	0.47	3	35	7.22
4	86	0.37	4	29	7.03
5	87	0.33	5	17	3.85
6	97	0.23	6	4	3.69
7	98	0.10	7	4	3.18
8	89	0.01	8	11	2.70

Table 2.2 Model structure of GLM models for determining the relative effect of traffic density and forest cover (2005 data). The same model structure was used with the 2006 data unless indicated otherwise.

Species	Type of Model	Response	Local Predictors	Landscape Scale Predictors
Wood Frog	Poisson	SC	Conductivity, Floating vegetation, Emergent vegetation	Wetland, Forest, Traffic
Spring Peeper	Gaussian	SC	pH, Pond perimeter	Wetland, Forest, Traffic
American Toad	Negative Binomial	SC	None	Wetland, Forest, Traffic
Leopard Frog*	Poisson	MSC	Pond perimeter, Overhanging vegetation, Surface vegetation	Wetland, Forest, Traffic
Gray treefrog	Negative Binomial	SC	Pond Perimeter	Wetland, Forest, Traffic
Green Frog**	Gaussian	Max # of Adults	None	Wetland, Forest, Traffic
Species Richness***	Gaussian	Species richness	Pond perimeter	Wetland, Forest, Traffic

Notes: SC = summed chorus counts; PA = presence/absence; MSC = modified summed chorus counts (summed chorus count, unless no frog was heard, but at least one was seen during a day survey in which case a value of 1 is recorded rather than 0).

* In 2006 the response was summed chorus counts.

** In 2006 the response was summed chorus counts and a Poisson model was used.

*** In 2005 the response was number of species seen or heard in visual and chorus surveys. In 2006 the response was based only on the number of species heard in chorus surveys.

Table 2.3 Frequency of occurrence of anurans at sampling ponds in both 2005 and 2006.

Both visual and call surveys were conducted in 2005, but only call surveys were conducted in 2006.

Species	Presence in 2005 (n = 36)			Presence in 2006 (n = 23)	
	% of ponds (call+ visual)	Number of ponds (call + visual)	Number of ponds (call survey alone)	% of ponds (call survey alone)	Number of ponds (call survey alone)
Wood frog	64	23	23	48	11
Western chorus frog	8	3	3	4	1
Spring peeper	92	33	33	87	20
American toad	47	17	17	74	17
Northern leopard frog	61	22	15	74	17
Gray treefrog	83	30	30	61	14
Green frog	100	36	32	100	23
Bullfrog	19	7	5	17	4
Mink frog	11	4	0	0	0

Table 2.4 Range and standard deviation (SD) of traffic density ($\Sigma\text{AADTm/m}^2$) and percent forest cover, along with the Pearson correlation between traffic density and forest cover at all spatial scales (100-2000 m radius from the edge of breeding ponds; n = 36).

Scale	Traffic Density		Percent Forest Cover		Correlation
	Range	SD	Range	SD	
100	0 - 44.3	9.85	0 - 100	45	-0.19
200	0 - 38.2	9.87	0 - 100	43	-0.19
300	0.02 - 29.5	8.87	0 - 100	42	-0.10
400	0.02 - 23.6	8.21	0 - 100	42	0.03
500	0.02 - 31.0	7.90	0 - 100	41	0.09
600	0.02 - 29.7	7.38	0 - 100	41	0.09
700	0.02 - 27.1	6.75	0 - 100	41	0.11
800	0.02 - 24.6	6.27	1 - 100	40	0.12
900	0.01 - 22.3	5.92	1 - 100	40	0.13
1000	0.01 - 20.3	5.48	1 - 100	39	0.15
1100	0.01 - 18.7	5.05	1 - 100	39	0.16
1200	0.01 - 17.2	4.69	2 - 100	38	0.18
1300	0.01 - 15.9	4.35	2 - 100	38	0.17
1400	0.01 - 14.8	4.11	2 - 99	37	0.16
1500	0.01 - 13.9	3.87	2 - 99	37	0.15
1600	0.01 - 13.0	3.66	2 - 99	36	0.15
1700	0.01 - 12.3	3.46	3 - 99	36	0.14
1800	0.01 - 11.6	3.29	3 - 99	35	0.14
1900	0.01 - 11.4	3.16	3 - 99	35	0.13
2000	0.01 - 11.2	3.03	3 - 99	35	0.12

Fig. 2.1 Study area, showing all sites ($n = 36$) surrounded by a buffer 1500 m in radius.

Fig. 2.2 Sampling design, with an example of each of the four types of landscapes: Low forest-low traffic, high forest-low traffic, low forest-high traffic, high forest-high traffic. Only four of the thirty-six landscapes are shown.

Negative response to forest and negative response to traffic

Positive response to forest and negative response to traffic

Fig. 2.3 Relative effects of traffic density and forest cover at 100 to 2000 m radius (scale) from the edge of sampling ponds (2005 data; $n = 36$). Panels are organized according to the type of response of each species or species richness (positive or negative) to the two predictors. The filled-in symbols indicate significant effects at $\alpha = .05$; hollow symbols

are non-significant. Note that explained deviance should not be compared between species.

Fig. 2.3 (Continued) Positive response to forest and negative response to traffic

Positive response to forest and positive response to traffic

Fig. 2.4 Relative effects of traffic density and forest cover at 100 to 2000 m radius (scale) from the edge of sampling ponds (2006 data; $n = 23$). Panels are organized according to the type of response of each species or species richness (positive or negative) to the two predictors. The filled-in symbols indicate significant effects at $\alpha = .05$; hollow symbols are non-significant. Note that explained deviance should not be compared between species.

Fig. 2.4 (Continued) Negative response to forest, negative response to traffic

Fig. 2.4 (Continued) Positive response to forest, negative response to traffic

Fig. 2.5a

Fig. 2.5 (a & b) The relationship species richness and traffic density ($\sum \text{AADTm/m}^2$) and percent forest cover (2.5a); the relationship between the relative abundance of six species of anurans and traffic density (2.5b) and forest cover (2.5c). All relationships are shown at the scale of the maximum effect for each species (2005 data).

Fig. 2.5b

Fig. 2.5c

CHAPTER 3: ACCESSIBLE HABITAT: AN IMPROVED MEASURE OF THE EFFECTS OF HABITAT LOSS AND ROADS ON WILDLIFE POPULATIONS

(Adapted from Eigenbrod F, Hecnar SJ, Fahrig L (2008) Accessible habitat: An improved measure of the effects of habitat loss and roads on wildlife populations. *Landscape Ecology* 23:159-168)

3.1 Chapter summary: Habitat loss is known to be the main cause of the current global decline in biodiversity, and roads are thought to affect the persistence of many species by restricting movement between habitat patches. However, measuring the effects of roads and habitat loss separately means that the configuration of habitat relative to roads is not considered. I present a new measure of the combined effects of roads and habitat amount: accessible habitat. I define accessible habitat as the amount of habitat that can be reached from a focal habitat patch without crossing a road, and make available a GIS tool to calculate accessible habitat. I hypothesize that accessible habitat will be the best predictor of the effects of habitat loss and roads for any species for which roads are a major barrier to movement. I conducted a case study of the utility of the accessible habitat concept using a data set of anuran species richness from 27 ponds near a highway. I defined habitat as forest in this example. I found that accessible habitat was not only a better predictor of species richness than total habitat in the landscape or distance to the highway, but also that by failing to consider accessible habitat I would have incorrectly concluded that there was no effect of habitat amount on species richness.

3.2 Introduction:

Habitat loss has negative consequences for populations and communities (reviews in Andren (1994) and Fahrig (2003)). In addition, the replacement of habitat with certain matrix cover types can create barriers or filters to the movement of individuals between habitat patches. Roads are thought to be a particularly strong barrier or filter for many species (Forman and Alexander 1998; Trombulak and Frissell 2000).

The effects of the loss of habitat and of roads on wildlife populations are usually evaluated using separate variables in landscape-scale studies. The effect of habitat loss is generally measured by the correlation between the amount of habitat in the landscape and species distribution or abundance, while the effects of roads are generally evaluated by the correlation between the density of roads/traffic in the landscape or the distance to the nearest road and species distribution or abundance (e.g. Gutzwiller and Barrow 2003; Johnson and Collinge 2004; Marchand and Litvaitis 2004). However, by considering habitat loss and roads as separate predictors, investigators do not account for the fact that habitat that can be accessed from a focal habitat patch without crossing a road is more likely to contribute to a population than habitat on the other side of the road. In addition, a road that needs to be crossed to access other habitat patches is likely to have a much greater negative effect on the population than one that does not restrict habitat access. Therefore, I hypothesize that measuring habitat loss and road effects on wildlife populations separately can lead to an underestimate of the effects of both stressors on wildlife populations.

In this chapter, I introduce a new landscape variable, 'accessible habitat', to measure the combined effects of habitat loss and roads which accounts for the location of

habitat in relation to roads. Several authors have previously used the term ‘accessible habitat’ when discussing areas that an organism could use as habitat (e.g. Anderson and Quinn (2007) for the portion of a river below a dam); however, to my knowledge I am the first to apply the concept to a focal-patch centred landscape ecology approach. I define accessible habitat as the amount of habitat that can be reached from a focal patch of habitat without crossing a road (Fig. 3.1), but other types of linear barriers (railroads, rivers, etc) could also be used to delineate accessible habitat.

The type of road (or barrier) used to delineate accessible habitat will be species-dependent. If a species avoids crossing any paved roads, paved roads should be used to delineate accessible habitat. However, if a species or taxon attempts to cross most or all roads, then only high-traffic roads should be used to delineate accessible habitat as smaller roads will only have a weak barrier effect.

I hypothesize that accessible habitat will be more strongly related to wildlife population persistence than total habitat amount and/or road density/distance to a road when populations are negatively affected both by habitat loss and roads. I present a case study of the utility of the accessible habitat concept using a data set of anuran species richness near a highway in eastern Ontario, Canada.

Case study: The effect of accessible forest on the species richness of frogs and toads near a major highway

Both the amount of forest and roads/traffic in the landscape are known to be important predictors of amphibian species richness, distribution and abundance. Many species of amphibians require upland habitat in the landscape along with ponds or

wetlands for breeding (Wilbur 1980). Forests can provide both upland habitat and help maintain the moist microclimate that facilitates the dispersal of amphibians (deMaynadier and Hunter 1999), and the amount of forest in the landscape around breeding ponds and wetlands is known to be positively associated with amphibian species richness (e.g. Laan and Verboom 1990; Hecnar and M'Closkey 1998; Knutson et al 1999; Findlay et al 2001; Houlahan and Findlay 2003; Herrmann et al 2005). The necessity of moving between multiple habitats and dispersing to re-colonize breeding sites means that many amphibians are also vulnerable to roads in the landscape. Studies have shown negative correlations between anuran species richness and paved road density (e.g. Findlay et al 2001); between anuran pond occupancy and road density (Vos and Chardon 1998); and between anuran relative abundance and traffic density (Fahrig et al 1995; Carr and Fahrig 2001; Eigenbrod et al 2008a). High-traffic roads have a greater negative effect on anurans than low-traffic roads (Van Gelder 1973; Fahrig et al 1995; Vos and Chardon 1998). I define habitat to be forest in my case study, and define accessible habitat (forest) to be the percentage of forest in the landscape that can be reached from sampling ponds without crossing a major highway.

The purpose of this case study was to answer the following question: Is accessible forest a better predictor of anuran species richness than either 1) the total amount of forest in the landscape; or 2) distance to the highway; or 3) the total amount of forest in the landscape and the distance to the highway? Given the vulnerability of anurans to both loss of forests and high-traffic roads, I predicted that accessible forest would be a better predictor of anuran species richness than total forest and/or distance to the highway.

3.3 Methods:

Study Design

I selected 27 ponds located 35 m to 3250 m away from a 58 km section of Highway 401 in a rural part of eastern Ontario (Fig. 3.2). Highway 401 is the main route connecting the two largest cities in Canada – Toronto and Montreal. In the study area, it is a limited access, four-lane divided highway with an average traffic volume of 18,300 vehicles/day in September 2006 (pers. comm., Mary Anne Griepsma, Ontario Ministry of Transportation). Traffic volumes at night are high (30% of traffic travels between 8 pm and 8 am) largely due to truck traffic: trucks constitute 56% of the night-time traffic volume, and 40% of the total daily traffic volume. Average traffic volumes on Highway 401 are relatively low compared to suburban highways where traffic volumes of 50,000-150,000 vehicles/day are not unusual (Forman and Deblinger 2000; Ontario Ministry of Transportation 2003). However, as most anuran movements are at night (Todd and Winne 2006), the high night-time traffic volumes mean that Highway 401 is likely to have a much greater negative effect on anuran populations than commuter routes with higher average daily traffic volumes, but lower night-time traffic volumes.

I defined accessible habitat (forest) as the amount of forest within 1000 m from the edge of a sampling pond that could be accessed without crossing Highway 401. The 1000 m distance is biologically relevant because it encompasses the majority of the migration and dispersal movements of the anuran species in my study area (Guerry and Hunter 2002). In addition, significant associations with the amount of forest have been observed for most anuran species found in the study area at this scale (Findlay et al 2001; Houlahan and Findlay 2003; Knutson et al 2004; Price et al 2004; Herrmann et al 2005).

All study ponds were at least 1 km apart to ensure independence of the sampling sites (Petranka et al 2004). As a result, only 4.7% of the total area of all landscapes was overlapping (Fig. 3.2). In addition, all study ponds were suitable for anuran breeding (no quarries, no fish hatcheries, at least some shallow water with emergent vegetation). I used every suitable pond in my study area within 500 m of the highway (14 in total) to minimize the correlation between total and accessible forest (which is 100% beyond 1 km from the highway), thus maximizing the statistical power of my analyses. The remaining 13 ponds were located up to 3250 m from the edge of the highway to maximize my ability to detect an effect of distance to Highway 401 on anuran populations.

Anuran field surveys

I conducted eight auditory night chorus surveys and four visual day surveys to assess the species richness of anurans at or near the sampling ponds in 2006. Nine of the 14 anuran species found in the Great Lakes basin (Harding 1997) are present in the study area: wood frog (*Rana sylvatica*), spring peeper (*Pseudacris crucifer*), western chorus frog (*Pseudacris triseriata*), northern leopard frog (*Rana pipiens*), American toad (*Bufo americanus*), gray treefrog (*Hyla versicolor*), green frog (*Rana clamitans*), mink frog (*Rana septentrionalis*) and bullfrog (*Rana catesbeiana*).

Chorus surveys were conducted between April 1 and July 12, 2006, and were timed so that there were at least two surveys during the peak breeding season of each species present in the region. Visual surveys were conducted between May 8 and July 8, 2006 to correspond with the peak breeding season of aquatic frogs (leopard frog, green frog, mink frog, bullfrog). Chorus and visual surveys followed the same protocol as

outlined in Chapter 2. The average survey temperature between April 1-May 9th was $9.3^{\circ}\text{C} \pm 4.1$ SD; between May 24th and July 12th it was $20.3^{\circ}\text{C} \pm 3.7$ SD. Once again, surveys were only conducted when there was little wind (average Beaufort wind scale reading 1.04 ± 1.15 SD). The total time spent at each pond for visual surveys varied from 2 to 121 minutes, with more time spent at ponds with a greater pond perimeter and higher amounts and densities of emergent vegetation.

Measurement of landscape variables

I quantified two landscape variables - percentage of forest and percentage of accessible forest - in landscapes of 1000 m radii from the edge of the sampling ponds. I also calculated the distance from the listening point at each pond to Highway 401, the amount of forest within 100 m of the edge of each pond, and the area of each pond. I did not quantify road density in my landscapes as Highway 401 was the only road within 1000 m of any of the sampling ponds with sufficient traffic volumes to present a significant barrier to anurans, and thus road density of major roads would have been redundant with distance to Highway 401. I calculated pond area in ArcGIS after measuring pond perimeter using a handheld GPS unit with sub-meter resolution (Trimble GeoExplorer, Trimble Navigation Ltd, Westminster, Colorado USA). I obtained the amount of forest in the landscape from digital 1:50 000 Natural Resources Canada topographic maps. All GIS work was performed with the ArcGIS 9.0 geographic information system (Environmental Systems Research Institute, Redlands, California, USA), mostly using custom tools that I wrote in the open source scripting language Python 2.1 (<http://www.python.org>). I wrote an ArcGIS tool in Python for calculating

accessible habitat that can be downloaded from the Geomatics and Landscape Ecology Research Laboratory (GLEL) website:

www.glel.carleton.ca/RESEARCH/accessiblehabitat.php This tool can be run within ArcGIS without any knowledge of the Python language.

Statistical analysis

Species richness was defined as the total number of species of anurans seen or heard during all surveys at each pond. I used multiple regression models to determine whether accessible forest, distance to Highway 401 or the combined effects of distance to Highway 401 and the total amount of forest or accessible forest in the landscapes was a better predictor of anuran species richness. All statistical models were run using the *lm* function in R 2.2 (R Development Core Team 2005).

I built eight statistical models containing pond area, amount of forest cover within 100 m of the pond, and 1) accessible forest; 2) total forest; 3) distance to Highway 401; 4) total forest + distance to Highway 401; 5) accessible forest + distance to Highway 401; 6) total forest + distance to Highway 401 + total forest*distance to Highway 401 7) total forest + accessible forest + distance to Highway 401; 8) total forest + accessible forest + distance to Highway 401 + total forest*accessible forest. I included pond area in all models as large ponds tended to extend farther away from the highway than small ponds located the same distance from the highway, and to control for the positive association between pond area and anuran species richness (Hecnar and M'Closkey 1998). I also included the amount of forest within 100 m of the pond edge in all models to account for between-pond differences in forested vernal pool habitat adjacent to the pond. I compared

the adjusted R^2 of the models, and also calculated the partial R^2 (amount of variation explained by each predictor after controlling for the variation explained by the other predictors in the model) (Zar 1999) of each of the predictors of interest. The statistical significance ($\alpha = 0.05$) of each predictor after controlling for the effects of the other predictors in the models was tested using an F -test with Type II SS using the *Anova* function in the *car* package (Fox 2006) within R 2.2. Type II SS conform to the principle of marginality and are more appropriate than Type III SS when interactions are present in the model. If no interactions are present, Type II SS are equivalent to Type III SS (Fox 2002). I log-transformed total forest, accessible forest and distance to Highway 401 to meet the assumption of homogeneity of variance. I checked for the presence of spatial autocorrelation in the residuals of all my statistical models by calculating Moran's I for all distance classes in spatial correlograms as discussed in Chapter 2.

3.4 Results:

The Pearson correlation between $\log(\text{total forest})$ and $\log(\text{accessible forest})$ was 0.56; the correlation between $\log(\text{accessible forest})$ and $\log(\text{distance to Highway 401})$ was 0.71; and the correlation between $\log(\text{total forest})$ and $\log(\text{distance to Highway 401})$ was 0.007.

Accessible forest was the best landscape predictor of anuran species richness, explaining 50% of the variation in species richness after controlling for local variables (Fig. 3.3a; Table 3.1). The best overall model included all variables and the interaction between total forest and accessible forest; this model explained 67% of the variation in species richness (adjusted R^2 of 0.57) (Table 3.1). Accessible forest was a much better

predictor of the effect of forest cover than total forest, which explained only 1% of the variation in species richness (Fig. 3.3c; Table 3.1). Accessible forest remained a significant predictor of species richness even after total forest and/or distance to Highway 401 was included in the model. There was no significant interaction effect between total forest and distance to Highway 401, but there was a significant interaction between total forest and accessible forest (Table 3.1), such that the relationship between total forest and species richness shifted from negative to positive with increasing accessible forest. There was no significant (α/K , where $\alpha = 0.05$ and $K = 11$) spatial autocorrelation in the residuals for any of my statistical models.

3.5 Discussion:

Case study

My results indicate that not measuring accessible habitat can lead to incorrect conclusions about the effects of habitat loss near barriers on wildlife populations. Total forest cover in the landscape was a very poor predictor of species richness, both in isolation and in combination with distance to the highway, while accessible forest was a strong predictor of species richness, even after controlling for distance to the highway. If I had not considered accessible forest I would have mistakenly concluded that there was no effect of forest cover on anuran species richness.

The significant interaction between accessible forest and total forest was caused by a negative effect of total forest on species richness when accessible forest was low, and a positive effect of total forest when accessible habitat was high. This occurred because there was frequently a large amount of forest on the far side of Highway 401

within 1000 m of the sampling ponds even when accessible forest was low (Fig. 3.2), resulting in relatively high total forest but low accessible forest. This non-accessible forest happened to be higher at sites with low species richness, leading to what was most likely a spurious negative correlation between total forest and species richness when accessible habitat was low. On the other hand, at sites where both accessible forest and total forest were high, most of the forest in the landscape was accessible (total forest and accessible forest were nearly identical), and thus total forest (and accessible forest) were both positively correlated with species richness.

The strength of the association (adjusted R^2 and partial R^2 values) of species richness with accessible forest and distance to Highway 401 suggests that this highway is a near-complete barrier to anurans, either because they avoid moving onto the highway and/or because of very high mortality rates when they attempt to cross. Unfortunately, I was unable to verify this by directly observing anuran mortality and behaviour on the highway, due to the high traffic volumes on the road. This supports findings showing genetic differentiation of anuran populations separated by major highways (Reh and Seitz 1990; Lesbarreres et al 2006). It is likely that the barrier effect of Highway 401 is due to mortality when crossing is attempted, as it is known that anurans often attempt to cross busy roads and that this results in very high mortality rates (Van Gelder 1973; Hels and Buchwald 2001).

The significant positive association between accessible forest and species richness after I controlled for distance to Highway 401 supports numerous other studies showing positive associations between forest cover and the species richness of this group of anurans (e.g. Houlahan and Findlay 2003; Herrmann et al 2005). Interestingly, Gagné and

Fahrig (2007) did not find a significant effect of forest cover on species richness in a study in the same region on the effects of urbanization on anurans. It is possible that inaccessibility of some of the forest in their study led to a reduction in the observed effect of this predictor. I also did not find a significant positive association with forest cover and species richness in Chapter 2 ($P = 0.075$, partial $R^2 = 0.10$ at the 500 m scale); post-hoc analyses revealed that accessibility of habitat was not an issue in Chapter 2 (total forest and accessible forest were highly correlated ($r = 0.96$)). I suggest that future studies investigating the effects of forest cover on amphibians at the landscape scale in areas with major roads should include accessible forest as a predictor variable, to evaluate the full effect of habitat amount and major roads on these species.

General Implications of Accessible Habitat for Wildlife Conservation

Accessible habitat has important implications for the conservation of many species of wildlife. An increasingly large body of literature shows that roads are barriers to the movement of a wide variety of species and taxa in addition to amphibians. These include ground beetles (e.g. Keller and Largiader 2003), bumblebees (Bhattacharya et al 2003), European badgers (Clarke et al 1998), small mammals (e.g. Oxley et al 1974), turtles (e.g. Steen and Gibbs 2004), bobcats and coyotes (Riley et al 2006), roe deer (Kuehn et al 2007), bighorn sheep (Epps et al 2005) and grizzly bears (Mace et al 1996).

My results suggest that accessible habitat is likely to be a better measure of habitat loss when barriers are present in the landscape than the total amount of habitat for species for which linear landscape elements present major barriers to movement. If the accessible fraction of the habitat is sufficient to support the needs of a species, it does not

matter whether or not roads prevent use of the habitat on the other side of the road, but including this non-accessible habitat in the analysis can obscure the effect of the biologically meaningful accessible habitat, as occurred in this case study.

Indeed, the importance of using accessible habitat versus total habitat will depend on the relationship between the non-accessible habitat and the accessible habitat. If the two are highly positively correlated, then including non-accessible habitat in the analysis (i.e. using total habitat as a predictor) should be nearly as good a measure of the effects of habitat loss on a species than if accessible habitat is used as the predictor. If, however, the non-accessible habitat is poorly or negatively correlated with accessible habitat (as occurred in this case study), then including it in the analysis (by using total habitat rather than accessible habitat as a predictor) can obscure the biologically real effect of accessible habitat by adding noise to the analysis. Consequently, failing to consider the location of habitat relative to the location of major barriers such as roads can lead to an underestimation of the effects of habitat loss in landscapes near roads (Fig. 3.1). This could lead investigators to then falsely conclude that habitat near roads is of little value to conservation.

A failure to consider accessible habitat could also lead to an underestimation of the effects of roads on wildlife populations, though this was not the case in my study. For example, if roads are complete barriers road density is likely to be a poor measure of the effects of roads as only the first road an animal reaches will be important. Likewise, distance to the nearest road will only be an appropriate measure of the effects of roads if a single road is delineating accessible habitat in all landscapes as multiple roads close to a

focal patch are likely to have a greater negative effect on wildlife than a single road and this will not be accounted for by measuring the distance to the nearest road (Fig. 3.1).

The utility of accessible habitat in measuring the combined effects of roads/barriers and habitat loss on wildlife populations will depend on the response of individual species to roads or barriers. Accessible habitat will be at least as good a measure of the effects of habitat loss as the total amount of habitat in the landscape and may be a better measure of the effects of roads than road density/distance to the nearest road when roads are a complete or near-complete barrier to movement. Based on the examples given earlier in the discussion, highways are likely to act as major barriers to movement for many if not most terrestrial animals, either due to avoidance of the road or due to very high mortality rates when crossings are attempted, as has been observed for frogs (Hels and Buchwald 2001), turtles (Aresco 2005) and European badgers (Clarke et al 1998). However, even minor roads may be a major barrier to movement for some species, such as salamanders (deMaynadier and Hunter 2000), invertebrates (Mader 1984), small mammals (Swihart and Slade 1984), and some snakes (Shine et al 2004), due to the behavioral response of these species to the road surface. Accessible habitat is likely to be less useful for measuring the effects of roads and habitat loss if individual roads only have a small negative effect on a species. In this case, road density is likely to be the best measure of the (cumulative) effect of roads in the landscape, and the total amount of habitat in the landscape may be a better measure of the effects of habitat loss than accessible habitat. Accessible habitat should be a worse predictor of the abundance or distribution of a species than the total amount of habitat in the landscape if linear features that are not barriers are used to delineate accessible habitat, as this will result in

an underestimate of the amount of biologically useful habitat in the landscape.

Measuring accessible habitat in addition to habitat amount and roads for different types of linear barriers can give an indication of the way in which a species responds to a particular type of road/barrier, because accessible habitat delineated by major barriers should be a better predictor of species abundance/persistence than accessible habitat delineated by weak barriers.

In conclusion, habitat loss and the effects of roads/linear barriers should not just be considered in isolation for species affected by both predictors, because doing so can lead to an underestimation of the effects of habitat loss and may also lead to an underestimation of the effects of roads/barriers on wildlife populations. I recommend that landscape ecologists should include accessible habitat in studies of the effects of both habitat loss and linear barriers on wildlife populations.

Table 3.1 Summary of statistical models ($n = 27$). The response variable for all models is species richness; pond area and amount of forest within 100 m of the pond edge are also included as predictors in all models. Statistical significance the F -statistic is indicated as:
 $* p < 0.05$; $** p < 0.01$; $*** p < 0.001$.

Model	Adjusted R^2 of model	Predictor	Coefficient	Partial R^2	F
1	0.33	log(Distance To Highway)	0.90 ± 0.23	0.40	15.13***
2	<0.00	log(Total Forest)	0.42 ± 0.94	0.01	0.18
3	0.44	log(Accessible Forest)	1.61 ± 0.34	0.50	22.93***
4	0.30	log(Distance To Highway)	0.9 ± 0.23	0.40	14.49***
		log(Total Forest)	0.34 ± 0.79	<0.00	0.19
5	0.44	log(Distance To Highway)	0.32 ± 0.32	0.04	0.97
		log(Accessible Forest)	1.23 ± 0.51	0.21	5.68*
6	0.28	log(Distance To Highway)	1.27 ± 0.85	0.40	13.97**
		log(Total Forest)	-2.32 ± 5.87	0.01	0.18
		log(Distance To Highway)* log(Total Forest)	0.40 ± 0.88	0.01	0.21
7	0.48	log(Distance To Highway)	-0.06 ± 0.38	0.00	0.02
		log(Total Forest)	-1.61 ± 0.94	0.12	2.91
		log(Accessible Forest)	2.04 ± 0.69	0.30	8.83**
8	0.57	log(Distance To Highway)	0.15 ± 0.36	0.00	0.18
		log(Total Forest)	1.86 ± 1.71	0.12	3.53
		log(Accessible Forest)	3.89 ± 1.01	0.30	10.71**
		log(Total Forest)* log(Accessible Forest)	2.47 ± 1.06	0.21	5.46*

Fig. 3.1 Hypothetical landscapes illustrating accessible habitat. In A, all habitat (dark grey) is accessible by some species from a focal sampling point (small black circle) without crossing a road (thick black line). In B, C and D accessible habitat (dark grey) is less than total habitat (light grey + dark grey). Distance to the nearest road is the same in landscapes B, C and D, but accessible habitat is lower in landscapes C and D. Road density is higher in landscape D than in landscape C but accessible habitat remains the same in both landscapes.

Fig. 3.2 Study area, showing sampling ponds, total forest cover and accessible forest cover (i.e. forest that can be reached from sampling ponds without crossing highway 401).

Fig. 3.3a

Fig. 3.3 (a-c) Relationship between residual anuran species richness and log-transformed (a) accessible forest within 1000 m of sampling ponds; b) distance to Highway 401 (m); c) total forest within 1000 m of the sampling ponds ($n = 27$). Residuals are from anuran species richness regressed against pond area and forest cover within 100 m of the pond edge. Residuals represent variation in the response not explained by the predictor variables, so this approach allows me to show the relationship between species richness and my landscape predictors (total forest, accessible forest and distance to the highway) independently of the effects of the local variables (pond area and amount of forest within 100 m of the pond) on species richness.

Fig. 3.3b

Fig. 3.3c

CHAPTER 4: QUANTIFYING THE ROAD EFFECT ZONE: THRESHOLD EFFECTS OF A HIGHWAY ON ANURAN POPULATIONS

(Adapted from Eigenbrod F, Hecnar SJ, Fahrig L Quantifying the road effect zone: threshold effects of a motorway on anuran populations in Ontario, Canada. In review)

4.1 Chapter Summary: The negative effect of roads on wildlife is recognized as a major contributor to the global biodiversity crisis, with anurans being among the most vulnerable groups overall. The ‘road effect zone’ - the extent of significant ecological effects from the edge of a road – (Forman & Alexander 1998), has important management implications, but has never been quantified for anurans. In the first study of its kind, I measured the extent and type of relationship underlying road effect zones of a highway with high night-time heavy truck traffic (Highway 401) for anuran species richness and relative abundance. I surveyed 34 ponds located 68 to 3262 m from the edge of the highway, and used piecewise and linear regressions to determine if road effect zones were clearly delineated by ecological thresholds. I found road effect zones of 250 – 1000 m delineated by ecological thresholds for four of seven species and species richness, and road effect zones of well beyond 1000 m best described by linear regressions for two species. Unexpectedly strong negative effects of Highway 401 on four of seven species suggest that, in addition to road mortality, very high night-time truck traffic can actually lead to reduced use of breeding habitat near the motorway either by acting as a barrier to habitat (forests) on the other side of the highway and/or due to traffic noise. My results show that most anurans are likely to have reduced abundances near motorways, but that both the extent of the effect of this type of road and the

underlying relationship vary considerably between species. Furthermore, the noise and/or barrier effect of very high night-time traffic volumes can lead to negative effects of motorways even on species that are relatively unaffected by direct road mortality.

4.2 Introduction:

The negative effect of roads on wildlife is recognized as a major contributor to the global biodiversity crisis for many taxa (Forman and Alexander 1998; Trombulak and Frissell 2000; Coffin 2007). While species as diverse as ground beetles (Keller and Largiader 2003) and grizzly bears (Mace et al 2006) are known to be negatively affected by roads, reptiles (e.g. Steen and Gibbs 2004) and amphibians (reviewed in Cushman 2006) are among the most vulnerable groups overall.

An important question for the management and mitigation of road effects on wildlife is how far from the road do its effects extend – the ‘road effect zone’ (Forman and Alexander 1998). Thus far, only four studies have quantified the extent of road effect zones. Reijnen et al (1995) found road effect zones (significant reductions in population density) for Dutch birds varied from 40-2800 m in width, depending both on the species and traffic volumes on the roads. Forman and Deblinger (2000) estimated the road effect zone of a major highway in Massachusetts for wildlife, based on adjacent land cover and information from existing literature, to be approximately 100 – 1000 m. Boarman and Sazaki (2006) showed that secondary highways result in a road effect zone of at least 400 m for desert turtles in the USA, while Semlitsch et al (2007) showed that minor forestry roads in the eastern USA resulted in a road effect zone of 35 m for salamanders. To date, no study has quantified road effect zones for anurans, despite the well-documented

vulnerability of this group to high-traffic roads (Fahrig et al 1995; Vos and Chardon 1998; Eigenbrod et al 2008a).

In addition to knowing its extent, it is also important for conservation biologists to know what type of relationship determines the road effect zone. A road effect zone can be delineated by an ecological threshold - a point or zone at which a relatively rapid change occurs from one ecological condition to another – (Huggett 2005; Luck 2005; Groffman et al 2006). A road effect zone is delineated by an ecological threshold if there is an abrupt transition from an effect of the road on a species to no effect (Fig. 4.1). The statistical significance of this transition (or ‘difference-in-slope’ parameter) can be tested using a piecewise regression (Muggeo 2003; Toms and Lesperence 2003). The main advantage for managers and policy makers of a road effect zone delineated by an ecological threshold is that the affected area will be clearly defined. In this case, decision makers do not need to consider the effects of the road beyond the threshold distance, and also have strong evidence for management actions to reduce the impact of the road up to the threshold distance. A road effect may also be revealed by a gradual increase in the abundance of some species with increasing distance from a road to the point beyond which no effect can be detected (Fig. 4.1). In this case, the road effect zone will not be as clearly defined as there is no threshold, making management recommendations more difficult.

The purpose of this chapter was to quantify the extent of the road effect zone of a motorway on anuran species richness and relative abundance. I used piecewise and linear regressions to determine if road effect zones are delineated by ecological thresholds, and at what distance from the motorway they occur. This chapter is the first study to

investigate the type of relationships that characterize road effect zones, and the first to quantify road effect zones for anurans.

4.3 Methods:

Study design

I selected 34 ponds located between 68 and 3262 m away from Highway 401 along a 58 km rural section of the highway in eastern Ontario, Canada (Fig. 4.2). I sampled all ponds in 2006, and re-sampled a 22 pond subset of these in 2007. Ponds were located at least 500 m apart to insure independence of sample sites (Petranka et al 2004). The 27 sites I used for my analyses in Chapter 3 were a subset of these 34 ponds.

Anuran field surveys

I conducted eight auditory night chorus surveys and four visual day surveys to assess the species richness and relative abundances of anurans at or near the sampling ponds in 2006 using the protocol outlined in Chapter 2. Surveys were only conducted on warm evenings (average survey temperature April 1-May 9th $9.3^{\circ}\text{C} \pm 4.1$ SD; May 24th-July 12th $20.3^{\circ}\text{C} \pm 3.7$ SD) with little wind (average Beaufort wind scale reading 1.04 ± 1.15 SD). I also conducted eight call surveys between April 2 and July 12, 2007, using the same protocol as in 2006. I conducted visual surveys between May 8 and July 8, 2006 to correspond with the peak breeding season of aquatic frogs (leopard frog, green frog, mink frog, bullfrog). Search effort was proportional to the density of emergent vegetation. The total time spent at each pond varied from 2 to 121 minutes, with more time spent at ponds with a greater pond perimeter and higher amounts and densities of

emergent vegetation. I also conducted four visual surveys between May 5 and June 26, 2007, using the same sampling protocol as in 2006.

Measurement of local variables

I quantified local pond variables to control for their effects in the statistical models. The local pond variables measured were: average pH, average conductivity, pond area, percent cover of emergent and floating vegetation within 2 m of the pond edge, amount of overhanging vegetation, degree of insolation (sun exposure), and amount of forest cover within 100 m of the pond edge. All measurements were taken in the spring/summer of 2006. I measured pH and conductivity at four points at each pond; both pH and conductivity can have significant effects on anurans (e.g. Weyrauch and Grubb 2004; Babbitt et al 2006). Species richness can be positively correlated with pond area (Laan and Verboom 1990). I measured pond area, using a handheld GPS unit with sub-metre resolution (Trimble GeoExplorer, Trimble Navigation Ltd, Westminster, Colorado USA). Overhanging vegetation may provide calling sites for treefrogs, and also affects the amount of sunlight at a pond, which, together with the amount of emergent and floating vegetation near the pond edge has been shown to affect the abundance of leopard and green frogs (Pope et al 2000; Carr and Fahrig 2001). I measured these local pond variables using the same protocol as outlined in Chapter 2 and obtained the amount of forest cover within 100 m of the edges of the ponds from digital 1:50 000 Natural Resources Canada topographic maps. The only exception to the protocol outlined in Chapter 2 for measuring local variables is that for two very small ponds the distance between transects was 10 m, whereas the minimum distance in Chapter 2 was 19 m.

Statistical analysis

Chorus surveys have been found to be a good indicator of the relative abundance of many species of anurans as discussed in Chapter 2. I used summed chorus counts as the response variable for all species except leopard frogs and green frogs (reasons below). Summed chorus counts give weight to ponds with both consistent calling and high numbers of calling individuals (Pope et al 2000). For green frogs and leopard frogs I used the maximum number of adults seen at a pond during the visual surveys as the response. Visual surveys have been shown to provide better estimates of green frog populations than chorus surveys (Nelson and Graves 2004) and chorus surveys can underestimate the presence of leopard frog populations (de Solla et al 2005). I also felt that I may not have heard the low, quiet calls of leopard frogs at ponds near Highway 401. I am confident that I was able to hear the calls of the other species over the noise of the highway. Only seven of nine species of anurans found in the study area were sufficiently common for species-level analyses. Species richness was the total number of species of anurans seen or heard during all surveys at each pond.

To quantify the road effect zones, I built a generalized linear regression and (where appropriate) a generalized, linear piecewise regression model for each species and for species richness. As the distribution of the response varied among species, I used a Gaussian, Poisson or negative binomial link function as appropriate. I used the *glm* function for the Gaussian and Poisson regressions, and the *glm.nb* function in the MASS package (Venables and Ripley 2002) for the negative binomial models. I used the package segmented 0.1-4 (Muggeo 2004) for the piecewise regression. All analyses were

performed in R 2.2 (R Development Core Team 2005). A piecewise linear regression with one breakpoint (Muggeo 2003; Toms and Lesperence 2003) is:

$$Y = a + b_1X_1 + \dots + b_jX_j + dD \text{ where } D \leq \text{breakpoint } T$$

$$Y = a + b_1X_1 + \dots + b_jX_j + dD + (d+e)(D-T) \text{ where } D > T,$$

where Y is the response, a is the intercept; $b_1 \dots b_j$ are the regression coefficients for all X_j local predictors; d = the slope for distance to Highway 401 (D) in the piecewise regression model to the left of the breakpoint (T); e = 'difference in slope parameter' so that $d + e$ is the slope of the line segment to the right of the breakpoint.

I only built piecewise regression models if an obvious breakpoint could be seen using a lowess smoothing function in the scatterplot between the response (after controlling for local variables) and distance to highway (Fig. 4.3), as recommended by Muggeo (2003) and Toms and Lesperence (2003). Piecewise regressions also require sensible initial estimates of the breakpoint (Muggeo 2003; Toms and Lesperence 2003) as the algorithm may otherwise converge to a local maximum rather than a global maximum if the initial estimate of the breakpoint is a long way from the true breakpoint. I ran piecewise regression models for each species and for species richness using ranges of estimates of the breakpoint (in 100 m intervals) based on visual inspection of the lowess smoothing function and the scatterplot of the data.

The piecewise and linear regression models for each species and for species richness included any local pond variable that was significant at $\alpha = 0.05$ in the last step of a preliminary stepwise multiple regression (Table 4.1). I used the *stepAIC* function in

MASS for these preliminary analyses, and included all local pond variables and distance to Highway 401 in these stepwise regressions.

I tested the significance ($\alpha = 0.05$) of the slope of the relationship between distance to Highway 401 and the response in the simple linear models. For the piecewise regression models, I tested the significance of the slope of the relationship between distance to the 401 before the breakpoint, and the significance of the ‘difference in slope parameter’. I used a chi-square test of significance for the Poisson and negative binomial models, and an F-test for the Gaussian models. I compared overall model fit of the linear and piecewise regression models for each species and for species richness using the AICc (AIC adjusted for small sample sizes) (Burnham and Anderson 1998) value.

I built statistical models as described above using just the 2006 data. I then ran the same models using the 2007 data to ensure that the breakpoints I found in 2006 were not simply a statistical artifact of the year in which sampling occurred. I checked for the presence of spatial autocorrelation of the residuals of the best-fitting model for each species (2006 data) by calculating Moran’s *I* for all distance classes in spatial correlograms as in Chapters 2 and 3.

4.4 Results

I found a statistically significant difference in slope parameter and that the piecewise regressions models gave a better fit to the data than the linear models for anuran species richness as well as for four of seven species of anurans (wood frog, spring peeper, the American toad, and the gray treefrog). The breakpoint occurred at approximately 450-800 m from the highway for species richness (two estimates of the

location of the breakpoint), 200-300 m from the highway for the spring peeper, American toad (two estimates of the breakpoint), and gray treefrog; and 600-1000 m from the highway for the wood frog (Table 4.2; Fig. 4.3). For species richness, the wood frog and the spring peeper, there was also a statistically significant relationship with distance to the highway up to the threshold distance (Table 4.2).

For one species – the leopard frog - there was no significant change in slope in the piecewise regression models and the linear regression model gave a better fit than the piecewise regression model, while for two species – green frog and western chorus frog – no piecewise regression was attempted as no threshold could be visually identified. The leopard frog and green frog did show a significant linear increase in abundance with increasing distance to the highway. There was no significant relationship between western chorus frog relative abundance and distance to the highway (Table 4.2; Fig. 4.3).

Results between 2006 and 2007 were generally very similar, with piecewise regression models providing a good fit to the data for the same species in both years. Indeed, the best estimates of the breakpoint in 2007 were within 100 m of the 2006 estimates for all piecewise regression models except for the wood frog, where the best estimate of the breakpoint was at 530 m from the highway in 2007 and 828 m from the highway in 2006 (Table 4.3; Figs. 4.3 and 4.4). A highly significant ($P < 0.01$) linear relationship between leopard frog abundance and distance to the highway was also present in both years, and no relationship with distance to the highway and chorus frog abundance occurred in either year. The only major change was for the green frog, for which there was no significant association with distance to the highway in 2007 ($P=$

0.60) (Fig. 4.4), as was present in 2006 (Table 4.2; Fig. 4.3). No significant spatial autocorrelation was detected for any species except the western chorus frog.

4.5 Discussion

My results show that road effect zones delineated by thresholds exist for species richness and for four of seven species of anurans, and that these extend from about 250 to 1000 m from the highway. Two other species – leopard frog and green frog – showed a significant negative response to proximity to Highway 401, but no threshold-type relationship. For these latter two species, the road effect zone appeared to extend at least 1000 m from the highway and possibly beyond 3000 m from the highway (Fig. 4.3). Road effect zones for anurans thus appear to vary widely among species both in their nature (threshold vs. linear response), and extent.

My findings indicate that comparing linear and piecewise regressions is a useful method to quantify the shape of the distance response of wildlife to roads. However, for two of the five statistically significant piecewise regression models, I found more than one estimate of the location of the breakpoint. This is likely a result of there being a zone where threshold effects exist, rather than a sharp break. Non clear-cut breakpoints may result in differences in breakpoint estimates and wide confidence intervals in the breakpoint (Muggeo 2003). Other types of piecewise regression models allow for a more gradual transition rather than a sharp break; however, these require the estimation of an extra parameter and are not recommended for relatively small sample sizes (Toms and Lesperence 2003). A log-transformation of distance to the road may also be very useful if the goal of an investigation is to measure the magnitude of the effect of a road on wildlife

and the data indicate a threshold-type response. Indeed, I found the strongest effect of distance to Highway 401 for the American toad ($P = 0.039$) and gray treefrog ($P = 0.008$) after log-transforming distance to the highway (2006 dataset). I did not include these findings in my main results as the purpose of this chapter was to quantify the road effect zone and not to estimate the magnitude of the effect of the road on anurans.

While my primary objective was to quantify the road effect zone, a major, unexpected, result was the strong, negative relationships between distance to the highway and relative abundance I found for four species that are generally thought to be relatively unaffected by roads and traffic – the spring peeper, wood frog, and, to a lesser extent, the gray treefrog and green frog (Carr and Fahrig 2001; Trenham et al 2003; Weyrauch and Grubb 2004; Mazerolle et al 2005; Chapter 2; but see Houlahan and Findlay 2003).

I hypothesize that the threshold-type relationships between anuran abundance and distance to Highway 401 I observed in this study and the unexpectedly strong negative effect of the highway on wood frog, spring peeper and gray treefrog abundance are both due to the reduced use of breeding habitat near Highway 401. There are two likely reasons for this:

- 1) Anurans are avoiding breeding sites near Highway 401, most likely due to the unusually high night-time noise levels on the highway interfering with calling activity. Amphibians could also avoid pollution from the highway such as road salt (Sanzo and Hecnar 2006), but this is unlikely in my study because runoff from the highway generally flows south and away from my sampling ponds. Heavy trucks make up 40% of the total traffic volume on Highway 401, and truck traffic volumes remain high at night (pers. comm., Mary Anne Griepsma, Ontario Ministry of Transportation), resulting in a near-

continuous rumble of traffic 24 hours a day. Most anuran calling (Oseen and Wassersug 2002) and movements are at night (Todd and Winne 2006), so night-time traffic volumes are likely to have a much greater negative effect on anuran populations than day-time traffic volumes. Avoidance of habitat up to some distance from a road can result in a threshold-type response, as has been shown for birds in the Netherlands (Reijnen et al 1995). In addition, there is some evidence that anuran calling may be negatively affected by anthropogenic noise. Sun and Narins (2005) found that *Microhyla butleri* – which gives a high-intensity call like the gray treefrog and spring peeper - reduced calling intensity due to low-frequency anthropogenic disturbances (traffic noise). Amphibians are also sensitive to seismic vibrations (Duellman and Trueb 1986), but the influence of ground vibrations on amphibian activity has received limited study. There may also be fitness costs for anurans that breed in a noisy environment. Barrass (1985) showed reductions in egg masses of *Bufo woodhousei* and *Hyla cinera* and disruptions in the mating systems of these species (reductions in non-calling males) in sites near a noisy highway compared to a control site, and there are preliminary indications that spring peepers increase both the intensity and frequency of their calling when subjected to recorded traffic noise (Glenn Cunningham, personal communication). Finally, a recent laboratory study showed a reduced ability of female treefrogs (*Hyla chrysoscelis*) to orient towards male advertisement calls in the presence of traffic noise (Bee and Swanson 2007). Highway 401 was completed in 1968 (Ontario Ministry of Transportation 2007), so small reductions in individual fitness may have accumulated into reduced populations near the highway over time.

2) Wood frog and spring peeper abundances near Highway 401 are low due to the inaccessibility of forest habitat on the other side of the 401. While the total amount of forest within 500 and 1000 m of the edge of the survey ponds was uncorrelated with distance to Highway 401, there was a high correlation between the amount of forest within 500 and 1000 m of Highway 401 that could be reached without crossing Highway 401 (accessible forest – Eigenbrod et al 2008b; Chapter 3) and distance to the highway (Fig. 4.5) ($r = 0.84$; $P < 0.0001$ and $r = 0.73$; $P < 0.0001$, respectively for the two distances). The amount of forest in the landscape is known to be the best single predictor of both spring peeper and wood frog abundance (Gibbs 1998; Houlahan and Findlay 2003; Regosin, Windmiller and Reed 2003; Homan, Windmiller and Reed 2004; Porej, Micacchion and Hetherington 2004; Gagné and Fahrig 2007; Chapter 2), with both species dependent on forests for foraging and breeding habitat. As the near-continuous flow of traffic on Highway 401 means that it is likely a near-complete barrier to the movement of anurans, the reduced forest cover available within 500 – 1000 m of ponds near the highway without crossing the highway likely has led to diminished populations of forest obligate species at these ponds.

Both traffic noise and the reduced forest cover within 500 – 1000 m of the pond are correlated with distance to Highway 401, so I am unable to say which of the above two hypotheses was most likely to be causal. Given the very strong associations of the wood frog and spring peeper with forest cover and the generally low vulnerability of these two species to roads and traffic, the reduced availability of forest near the highway is likely the major reason for the observed relationship for these two species. However, as there is no threshold in the relationship between accessible forest and distance to the highway

(Fig. 4.6), it seems probable that at least some of the reduced abundances of the spring peeper and wood frog near the highway were due to an avoidance of breeding ponds near the highway. It is likely that avoidance of noisy ponds was the main factor leading to the threshold response of the gray treefrog and American toad, as these species are habitat generalists only weakly associated with forest cover (Trenham et al 2003; Herrmann et al 2005; Gagné and Fahrig 2007; Chapter 2). Traffic mortality may also have played a role in the low abundances of the American toad near the highway. I showed that there is a significant negative association between this species and traffic density in the landscape in Chapter 2, and the related European toad (*Bufo bufo*) is also known to be very vulnerable to road mortality (Schlupp and Podlouscky 1994; Hels and Buchwald 2001) as well.

The linear response of leopard frogs and green frogs to distance from the highway suggests these two species were not avoiding breeding habitat near the highway, but rather that their low abundance near the highway was caused by road mortality. The leopard frog is known to be very vulnerable to high-traffic roads (Carr and Fahrig 2001; Chapter 2), likely due to high road mortality (e.g. Ashley and Robinson 1996). While no previous study has shown a significant effect of road traffic on green frog populations (Carr and Fahrig 2001; Chapter 2), my results in Chapter 2 did suggest that this species is vulnerable to very high traffic volumes in the landscape. Given that green frog movement is mainly at night, it is likely that Highway 401, with its high night-time traffic volumes, has a much greater negative effect on the green frog than other high-traffic roads with similar overall traffic volumes but less night-time traffic. The lack of a relationship between green frog abundance and distance to the highway in 2007 does suggest that this

species is less adversely affected by traffic than the leopard frog, as suggested by the literature. The low amounts of accessible forest cover in the landscape near the highway may also have contributed to the observed relationships for these species, though the amount of forest cover in the landscape is generally not an important predictor of either green frog or leopard frog presence or abundance (Guerry and Hunter 2002; Gagné and Fahrig 2007; Chapter 2; but see Houlahan and Findlay 2003). Both green and leopard frog abundances are clearly lower near Highway 401, but with their abundances still increasing 3000 m from the highway, the extent of the road effect zone for these two species is difficult to define.

The lack of any significant relationship between western chorus frog abundance and distance to the highway was not unexpected, as both Dr. Fred Schueler and I observed that the very patchy distribution of this species in eastern Ontario appears to be unrelated to traffic volumes at the landscape scale. Given the lack of an observed relationship, the spatial autocorrelation of the residuals for this species does not affect my results.

While many studies have demonstrated that the negative effects of roads on amphibians extend considerable distances into the landscape (reviewed in Cushman 2006), I believe my study is the first to show that both the extent and the type of response of amphibians to roads can vary among species. While the strongest effect of the highway is within 250 m (six of seven species negatively affected), large reductions in species richness and in the abundances of the wood frog and green frog occur up to at least 500 m from the road, and leopard frog populations may be affected up to 3000 m from the highway. Given that Highway 401 has a total length of approximately 800 km, even a road effect zone only 500 m wide translates into over 800 km² of land adjacent to the

highway being of limited use to at least some species of anurans. It is likely that similar road effect zones exist for other major intercity truck routes throughout North America and Europe.

In addition to demonstrating the impacts of major intercity truck routes on anuran populations, my results add to the growing body of information on the effects of different types of roads on anurans. Previous studies have shown that high-traffic roads have a stronger negative effect on anurans than on low traffic roads (Fahrig et al 1995; Hels and Buchwald 2001), and forestry roads with very low traffic volumes have no effect on anuran movements (deMaynadier and Hunter 2000). My results suggest very high night-time truck traffic volumes can actually lead to reduced use of breeding habitat near these types of roads either by acting as a barrier to habitat on the other side of the road and/or due to traffic noise, leading to increased negative effects of these types of roads on species that are generally unaffected by traffic mortality, such as the spring peeper and wood frog. More research is needed to establish if my findings for Highway 401 also hold near other major transportation routes, and if threshold night-time traffic volume leads to avoidance of habitat near motorways. More work is also needed to test the hypothesis that anurans reduce their use of breeding habitat near major roads due to traffic noise.

Table 4.1 Local pond variables included in both the linear and piecewise regression models. These variables were significant at $\alpha = 0.05$ in the last step of a preliminary stepwise multiple regression which included all local pond variables as well as distance to Highway 401.

Response	Local Variables
Species Richness	Pond Area, Surface Vegetation
Wood Frog Summed Calling	Surface Vegetation, Emergent Vegetation
Western Chorus Frog Summed Calling*	Forest Cover within 100 m of pond edge
Spring Peeper Summed Calling	pH, Surface Vegetation
Leopard Frog Maximum Adults	Conductivity, Surface Vegetation
American Toad Summed Calling	pH
Gray Treefrog Summed Calling	Pond Area
Green Frog Maximum Adults	None

*The initial stepwise regression to identify important local variables performed very poorly for this species. I ran a second stepwise regression using the best two predictors from the first stepwise regression; the results of the latter analysis are shown here.

Table 4.2 Summary of statistical models. In cases where more than one breakpoint was estimated (*), only the estimate from the best-fitting model is shown. Statistical significance of the coefficients is indicated as follows: * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$. N/A indicates that no piecewise regression was attempted as no threshold was apparent from visual examination of the data.

Response	Simple Linear Model		Piecewise Regression Model			Difference in Slope Parameter
	AICc	Slope: Distance to Highway	AICc	Breakpoint	Slope before breakpoint	
Species Richness	124.7	0.0012 ±0.0003***	119.8	640.9 ±183.1*	0.0049 ±0.0015***	-0.0045 ±0.0016**
Wood Frog	94.2	0.0012	94.1	827.8	0.0038	-0.0034
Summed Calling		±0.0003***		±204.7	±0.0016***	±0.0016*
Western Chorus Frog Summed Calling	83.3	0.0003 ±0.0004	N/A	N/A	N/A	N/A
Spring Peeper Summed Calling	200.7	0.0003 ±0.0002	189.6	273.8 ±55.77	0.0094 ±0.0047*	-0.0094 ±0.0047***
Leopard Frog Maximum Adults	154.6	0.0007 ±0.0002**	156.7	935.9 ±412.0*	0.0019 ±0.0009**	-0.0016 ±0.0010
American Toad Summed Calling	112.6	0.0002 ±0.0001	109.0	246.4 ±56.35*	0.0107 ±0.0041	-0.0106 ±0.0041*
Gray Treefrog Summed Calling	129.2	0.0004 ±0.0002	127.2	245.9 ±54.1	0.0163 ±0.0101	-0.0162 ±0.0101**
Green Frog Maximum Adults	246.0	0.0003 ±0.0001*	N/A	N/A	N/A	N/A

Notes: I used a Gaussian link function for species richness and a Poisson link function for the American toad; all other analyses use the negative binomial link function.

Table 4.3 Comparison of breakpoint estimates ($\pm$ one SD) from 2006 and 2007 based on piecewise regressions. In cases where more than one breakpoint was estimated (*) (e.g. American toad in 2006), only the estimate from the best-fitting model is shown. N/A indicates that no statistically significant ($P < 0.05$) ‘difference in slope’ parameter was present, or that no piecewise regression was attempted as no threshold was apparent from visual examination of the data.

Response	Breakpoint (2006)	Breakpoint (2007)
Species Richness	640.9 $\pm$ 183.1*	675.4 $\pm$ 245.2
Wood Frog Summed Calling	827.8 $\pm$ 204.7	529.94 $\pm$ 94.59*
Western Chorus Frog Summed Calling	N/A	N/A
Spring Peeper Summed Calling	273.8 $\pm$ 55.77	211.8 $\pm$ 26.56
Leopard Frog Maximum Adults	N/A	N/A
American Toad Summed Calling	246.4 $\pm$ 56.35*	149.8 $\pm$ 27.1
Gray Treefrog Summed Calling	245.9 $\pm$ 54.1	316.2 $\pm$ 98.0*
Green Frog Maximum Adults	N/A	N/A

Fig. 4.1 An example of two types of road effect zones; one sharply defined by a threshold and the other characterized by a gradual increase in population size with increasing distance from the road

Fig. 4.2. Map of the study area. The area shown is located in eastern Ontario, approximately 100 km south of Ottawa and 100 km southwest of Montreal, with the St. Lawrence River forming the boundary between Canada and the USA.

Fig. 4.3a

Fig. 4.3 (a-h) Relationship between anuran relative abundance/species richness and distance to Highway 401 (residuals after controlling for significant local predictors) in 2006 ($n = 34$). The lowess smoothing line is shown. For species fitted with a piecewise regression model, the breakpoint of the best fitting model is shown by heavy solid vertical line; the second best-fitting breakpoint for the American toad and species richness is shown by the second solid vertical line. One standard deviation below the smallest breakpoint and one SD above the largest breakpoint are shown (dashed vertical lines).

Fig. 4.3b

Fig. 4.3c

Fig. 4.3d

Fig. 4.3e

Fig. 4.3f

Fig. 4.3g

Fig. 4.3h

Fig. 4.4a

Fig. 4.4 (a-h) Relationship between anuran relative abundance/species richness and distance to Highway 401 (residuals after controlling for significant local predictors (Table 4.1)) in 2007 ($n = 22$). The lowess smoothing line is also shown. For species fitted with a piecewise regression model, the breakpoint of the best fitting model is shown by heavy solid vertical line; the second best-fitting breakpoint for the American toad and species richness (and the second and third best-fitting breakpoints for the gray treefrog) are shown by additional solid vertical lines. One standard deviation below the smallest breakpoint and one SD above the largest breakpoint are shown (dashed vertical lines).

Fig. 4.4b

Fig. 4.4c

Fig. 4.4d

Fig. 4.4e

Fig. 4.4f

Fig. 4.4g

Fig. 4.4h

Fig. 4.5 Example of the difference between the total amount of forest cover within 1000 m radius of a sampling pond (black dot) and the amount of forest that can be reached without crossing Highway 401 (accessible forest) (parallel heavy black lines). Forest cover is shown in grey; with forest cover on the other side of Highway 401 from the sampling pond in light grey.

Fig. 4.6 Relationship between distance to Highway 401 and amount of forest available without crossing Highway 401 within 500 m of the pond edge (accessible forest).

GENERAL CONCLUSIONS:

My dissertation makes four major contributions to the field of ecology: 1) sub-optimal study design has major impacts on landscape-scale inference; 2) road traffic has at least as large a negative effect on the anurans of eastern Ontario as does deforestation; 3) habitat loss near major roads should not be measured independently of the roads; 4) the road effect zone of a major intercity highway for anurans extends at least 500 m into the landscape.

Of these findings, the main result of Chapter 1 - that sub-optimal study design has a major impact on landscape-scale inference - has the widest-ranging implications for conservation. A number of papers have discussed the experimental design of landscape ecological studies (Klopatek and Gardner 1996; Brennan et al 2002; McGarigal and Cushman 2002), but none of these has tested the implications of sub-optimal design. Although the macroecological literature includes examples of tests of the impact of spatial autocorrelation on regression coefficients (e.g. Lennon (2000); Diniz-Filho et al (2003)), such studies focus on this one aspect of experimental design in spatial ecology alone. To my knowledge, I am the first to demonstrate that sub-optimal study design alone can lead to incorrect inferences in landscape ecology. Of particular importance was the finding that slightly non-monotonic relationships between forest cover and anuran abundance (Fig. 1.2) can lead to a switch in the sign of the relationship between forest cover and the abundance of these species when only a portion of the full range of forest cover is considered. In general, it seems that the combined impact of a non-monotonic relationship and using only a portion of the predictor of interest on experimental design is rarely considered by ecologists. Collinearity of predictors, on the other hand, is known to

be a major issue by most ecologists (e.g. Diniz-Filho et al 2003; Houlahan and Findlay 2003) and is well documented in the statistical literature (e.g. Grafen and Hails 2002), though as McGarigal and Cushman (2002) point out, this knowledge often does not translate into best practice. My findings make it clear that sound experimental design is crucial to making correct inferences in landscape ecology, and that investigators must at the very least point out the potential impacts that shortcomings in experimental design might have on their conclusions.

My findings in Chapter 1 raise a number of intriguing questions for future research. The effects of broad-scale trends on the abundance of the wood frog suggest that regional factors such as climate, soil or vegetation type might be more important than landscape-scale factors like forest cover at the edge of a species' range. Does this relationship still hold at the centre of the range? There is a large literature examining the relationships between species abundance across species' ranges (e.g. Brown 1995; Sagarin et al 2006) and of the factors determining range limits (see Bridle and Vines (2007) for a recent review). However, to my knowledge the relative effects of landscape-scale factors and regional factors are poorly understood. Large-scale datasets such as the Michigan and Wisconsin Frog and Toad Surveys or the North American Breeding Bird Survey are probably best suited to answering these sorts of questions. A challenge for this type of analysis would be to find regions that all have a large number of landscapes and where all regions have a similar range of landscape-scale predictor variables.

The second chapter of my dissertation provides further evidence for the importance of sound experimental design within landscape ecology. By considering traffic density independently of the amount of forest in the landscape and by ensuring a

wide range of both predictor variables, I showed that traffic density had a much greater effect on anuran species richness than deforestation. The most significant finding of this chapter is that it clearly demonstrates that road traffic has at least as great an effect on anurans as the loss of forests. Several authors have pointed out that this is likely (e.g. Lehtinen et al 1999; Findlay et al 2001; Cushman 2005), but this chapter is the first study to conclusively show that this is actually the case. I also show that anurans vary widely in their susceptibility both to traffic and deforestation, providing further support to the findings of Carr and Fahrig (2001) and, among others, Guerry and Hunter (2002), Knutson et al (2004) and Gagné and Fahrig (2007). Finally, my results suggest that the strong positive association with forest cover and anuran and amphibian species richness in the literature (Hecnar and M'Closkey 1998; Kolozsvary and Swihart 1999; Lehtinen et al 1999; Findlay et al 2001; Houlahan and Findlay 2003; Herrmann et al 2005) may not be entirely due to forest cover per se, but partly a result of strong correlations between forest cover and traffic and/or urbanization in many of these studies.

My findings in Chapter 2 also raise a number of more general questions. For example, do agrochemical inputs (discussed in the Introduction) have a greater effect on the abundance of any species than habitat loss if the former is measured independently of the latter? Also, are there taxa other than anurans for which the effects of roads are at least as great as habitat loss? It seems this is likely true for turtles (e.g. Gibbs and Steen 2005), some generalist species such as European badgers (e.g. Clarke et al 1998), and large carnivores (e.g. Riley et al 2006), but it may also be the case for a number of other taxa if habitat loss is measured independently of high-traffic roads.

Having established the importance that road traffic has on anurans relative to deforestation in Chapter 2, I focused in Chapter 3 on how best to measure the effects of these two important predictors on wildlife. I showed that accessible habitat – the amount of habitat that can be reached from a focal patch without crossing a road or other major barrier – may be a much better measure of the impacts of both habitat loss and/or the road than measuring these two variables independently. Accessible habitat has important implications for the management of the many species (Chapter 3) that are affected by both habitat loss and roads. However, if the barrier effect of a road is low, then accessible habitat may not be a better measure of the effect of roads or habitat loss than considering the two predictor variables independently. I recommend measuring both accessible habitat and habitat loss and roads independently, and then using an information-theoretic approach (Burnham and Anderson 1998) or adjusted R^2 to select the most parsimonious model.

A future application of the accessible habitat approach is to use it to test the relative barrier strengths of different types of roads. I would predict that, all other factors being equal, accessible habitat would be a better predictor of species abundance than total habitat when the barrier effect of a road is strong, but a worse predictor of abundance than total habitat when a barrier is weak as it would fail to account for the availability of useful habitat on the other side of the road.

In Chapter 4, I focused on the effect of one road with very high night-time heavy truck traffic – Highway 401 – on anuran populations. In doing so, I addressed a shortcoming of Chapter 2 where I looked at a large range of traffic densities, but, due to logistical considerations, was only able to include three sites with high night-time traffic

volumes. In Chapter 2 I showed that four species unaffected by traffic density in Chapter 2 - the spring peeper, wood frog, gray treefrog, and green frog – showed significant negative associations with proximity to the highway. I also show that a road effect zone (Forman and Deblinger 2000) of 500 m exists for Highway 401 for anuran species richness, and that road effect zones of at least 1000 m exist for the green frog and leopard frog. The main implications of this chapter for conservation are that major intercity highways have negative effects on anurans above and beyond those of ‘normal’ high-traffic roads and that these extend at least 1000 m into the landscape. More work is needed to try to disentangle the effects of traffic noise and avoidance from the well-documented effects of direct mortality (e.g. Ashley and Robinson 1997; Hels and Buchwald 2001) on anurans.

Chapter 4 also has implications for the conservation of species other than anurans. For one, it demonstrates that piecewise regressions – which are used infrequently in ecology (Toms and Lesperence 2003) – can be used both to delineate road effect zones and to determine whether or not a species exhibits a threshold-type response to a road. Secondly, this chapter suggests that night-time traffic volumes may be a better measure of the impacts of roads on anurans than total traffic volumes; is this also true for other nocturnal species?

An overarching goal of my dissertation has been to advance our understanding of the effects of deforestation and roads on wildlife by testing hypotheses in such a way that Popper’s (1962) ideal of each alternative outcome allowing the exclusion of at least one alternative hypothesis is achieved. My approach throughout has been to set up what McGarigal and Cushman (2002) and Hurlbert (1984) term mensurative experiments,

where the system of interest is measured at different locations and times. By carefully selecting my sites to maximize variability of the landscape-scale predictor(s) of interest and minimizing correlations with potentially confounding variables, I have been able to gain several important insights into the relationships between anurans, roads and forests, and, more generally, into the impacts of study design in landscape ecology. Mensurative studies are often the best available option when working at the landscape scale, given that manipulative experiments are often impractical and/or unethical to carry out at this scale (McGarigal and Cushman 2002). This dissertation shows that carefully designed mensurative studies are vital if the discipline of landscape ecology is to continue to provide accurate, clear guidelines for conservation planning.

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Appendix 1: Description of data for Chapter 1 and R code for selecting random subsets of sites with high overlap

Description of data

All data used in Chapter 1 is publicly available from either the Michigan or Wisconsin Frog & Toad Monitoring programs by emailing the coordinators, or from the USGS (land cover data). See the Methods section of Chapter 1 for more details. I have included several electronic documents giving the exact sites I used for the analyses in Chapter 1 on the attached CD in the folder labelled 'Appendix1Data'. This CD is available upon request from the Carleton University Library.

The documents on the CD that pertain to Appendix 1 are as follows:

AllSites.xls - The 1141 sites from the Michigan and Wisconsin Frog & Toad survey datasets used in this analysis. SITECODE is the original unique ID used by the Michigan survey; ROUTESITE the unique identifier used by the Wisconsin survey. Note that I created a ROUTESITE code for the Michigan sites, thus creating a unique identifier for every site which I then used for all analyses. STATE gives the state (Michigan or Wisconsin from where the data came). Xcoord and Ycoord are the XY coordinates of the sites. The projection (USA Contiguous Albers Equal Area Conic (ArcGIS 9.1 ((Environmental Systems Research Institute, Redlands, California, USA) designation); the datum NAD83. All available data collected between 1996 and 2002 from each of these sites was used in the analysis. See the Methods of Chapter 1 for more details.

BaseAnalysis.xls - The list of sites ($n = 50$) for each of the 1000 random subsets I used to test Pitfall 1 (Selecting the incorrect spatial scale for analysis) and Pitfall 5 (The existence of broad-scale spatial trends confounding landscape-scale effects). I also used these subsets as the control group (no overlap at 10,000 m) to test Pitfall 2 (Using landscapes that overlap in space)). All sites were selected by ROUTESITE from the 1141 sites listed in AllSites.xls

Pitfall2OverlapLandscapes.xls The list of sites ($n = 50$) for each of the 1000 random subsets I used to test Pitfall 2 (Using landscapes that overlap in space). The R code I used to select these sites is given at the end of this Appendix. All sites were selected by ROUTESITE from the 1141 sites listed in AllSites.xls

Pitfall3.xls The five sets of 1000 random subsets of 25 sites I used to test Pitfall 3 (Using only a portion of the potential range of the landscape predictor variable of interest). The list of sites for each set of sites is on a separate worksheet. All sites were selected by ROUTESITE from the 1141 sites listed in AllSites.xls

Pitfall4.xls The two sets of 1000 random subsets of 50 sites I used to test Pitfall 4 (Failing to account for correlations among landscape predictor variables). The list of sites for each set of sites is on a separate worksheet. All sites were selected by ROUTESITE from the 1141 sites listed in AllSites.xls

R code for selecting random subsets with high overlap at the 10,000 m scale (Pitfall 2 - Using landscapes that overlap in space)

```
#
# ##### Code to select clusters of points (as large as possible) that are within
# # some minimum distance (e.g. within 10,000 m) of each other
#
AllSitesAnalysis <- read.csv("AllAnalysisData_MI_WI5Years.csv")
#str(AllSitesAnalysis)
#
##### Don't actually need most data for site selection, so subset..
# #just including ROUTESITE, Route, and xy coordinates...
AllSites <- AllSitesAnalysis[,c(1,2,7,8)]
#
subset.df <- AllSites
#
#
str(subset.df) #error check
#print(sort(subset.df[,1])) #error check
#
overlapping <- matrix(nrow = 1000, ncol = 50) # empty data matrix
#
##### set the number of desired subsets
columns <- c(1:1000)
#
##### Now loop through the subsets....#####
#
y = 0 # subset counter
#
for (col in columns)
{
y = y+1
#print(y) #error check
#
##### create an initial list of sites ###
##### this becomes smaller as sites are used within a subset...
sites <- subset.df$ROUTESITE
#
### and create an empty list to place the subset in
list_sites <- c()
#
# # Now produce a subset using the 'while' loop
# # set length to being less than sample size..
##### #####
```

```

while(length(list_sites) < 50)
{
# # select a random site
random1 <- sample(sites,1)
#sites[sites %in% c(random1)] #subsetting sites..
#
# ### find the position of the selected sites within 'sites'
col_ <- match(random1,sites)
#
attach(subset.df)
#
#####Select the desired sites within the subset#####
### Could also be done within the whole dataset? ###
#
rows <- nrow(subset.df) # number of sites in the subset...
XY_RouteXY <- cbind(X_Coord,Y_Coord)
Distance <- dist(XY_RouteXY)
matrix <- as.matrix(Distance) #create matrix from distance object
#
# col_ comes from sample() above...
c1 <- matrix[col_,]
# # the columns below the random column...
c2 <- cbind(c1[col_ :rows],ROUTESITE[col_ :rows])
#
# # now number of columns above the random column
temp <- rows - col_
col1 <- rows - temp - 1
c3 <- cbind(c1[1:col1], ROUTESITE[1:col1])
#
##### now want combine c1 and c2 and subset and select only
##### those sites that meet the conditions (distance)
s1 <- rbind(c2,c3)
colnames(s1) <- c("dist", "ROUTESITE")
s1 <- as.data.frame(s1)
s2 <- subset(s1,dist < 10000)
#
detach(subset.df)
#
##### Now want to add selected sites to the list of sites...
s3 <- s2$ROUTESITE
print("random1")
print(random1) #error check
print("new sites")
print(s3) #error check
print("old list")
print(list_sites)

```

```

# First remove any overlapping sites
### Note: if 'nomatch' get 'NA' or '0' problematic. Thus..
matching <- match(s3, list_sites, nomatch = 0)
matching1 <- matching[matching > 0] # get rid of zero values
#However, if only have zero values, this causes problems. So..
summatch <- sum(matching)
#
# ##### if block #####
if (summatch > 0) {
list_sites <- list_sites[-c(matching1)]
} else {
list_sites <- list_sites
}
# ##### end of if block
#
# Now add new sites...
list_sites <- c(s3,list_sites)
#
print("new list sites")
print(list_sites) #error check
#
# ### Now want to remove the sites in 'list_sites' from the total site list...
#
matching2 <- match(list_sites, sites, nomatch = 0)
print("matching2")
print(matching2)
matching3 <- matching2[matching2 > 0] # get rid of zero values
print("matching3")
print(matching3)
summatch2 <- sum(matching2)
# ##### if block #####
if (summatch2 > 0) {
sites <- sites[-c(matching3)]
} else {
sites <- sites
}
# ##### end of if block
print("sites after matching")
print(sites)
# ##### end of while loop
}
#
list_sites <- list_sites[1:50] # limit to 50
overlapping[y,1:50] <- list_sites
#
dev.next() #END OF SUBSET LOOP #####

```

```
}  
# #### now write output to .csv file...  
write.csv(overlapping, "OverlappingSubsets.csv")  
# #### NOTE: Need to go into excel and remove row and column headings of the .csv  
# ## file before using for subset selection in the analyses.
```

Appendix 2: Raw field data for Chapter 2 (2005 and 2006 data)

Electronic versions of this data and the summarized version of this data used in the analyses are available electronically on the attached CD and is available upon request from the Carleton University Library. The files 'RawData2005.xls' and 'RawData2006.xls' contain all information in Appendix 2 except site and pond information. The also contain additional data on tadpole and juvenile frogs, as well as field notes. None of this additional information was used in any part of this thesis as I judged it not to be 100% reliable. 'Chapter2DataSummary.xls' contain the summary files used for analysis, site and pond information, and the amount of forest, wetland and traffic in the landscape at the 100 to 2000 m scale.

Chapter 2 Pond information. IMPORTANT: The X and Y coordinates are NOT a guarantee of access to any site, but especially not to sites on private land. DO NOT attempt to access any sites on private land without first contacting the landowners. Please also contact me (felix.eigenbrod@gmail.com) BEFORE re-surveying the sites if you are interested in doing so; I may be able to provide additional information on who owns the land on which the sites are located which I cannot make public due to confidentiality agreements.

Site coordinates are in UTM (Zone 18N); the datum is NAD83.

* indicates the 2 sites that were not used in the final analysis.

pH and conductivity are averages from 4 points on the edge of each pond located a maximum distance apart and were collected in 2005. Pond perimeter was measured in 2005 using a Trimble GPS. More information is available in the methods of Chapter 2.

Site	Private?	X coordinate	Y coordinate	Conductivity	pH	Pond Perimeter (m)
8thLine	Y	462300.2	5037201	75.75	7.315	119.72
AbandonedFarm	Y	462170.3	4970809	111	7.535	327.6892
Bank	Y	461640.7	5020560	147.25	9.2675	222.42
Bilmer	Y	509822.7	5043698	147.50	7.74	59.10
Bouvier	Y	482103.7	5051372	79.25	8.47	114.41
Buckwheat	Y	455217.1	4987095	592.00	7.51	242.25
Carbine	Y	392674.6	5040720	83.00	8.46	157.58
CercleDesErables	?	434902.3	4991582	43.75	7.15	416.66
Ducks_Unlimited	Y	511677.8	5010961	233.75	8.32	438.61
FrenchSettlement	Y	451078.5	4986023	51.25	7.24	44.93
Galetta*	Y	432869.5	5048070	402.75	8.93	130.8379
GatineauPark	N - National Capital Commission land	470922.2	4987765	43.50	6.67	531.71
Gibson's	Y	410291.5	5025337	539.50	7.77	82.70
GoldenLine	?	502433.8	4998810	201.25	8.72	139.67
GravelPit	Y	515604.2	4999633	186.00	8.98	137.73
Groulx	Y	467470.1	5041046	495.50	6.89	349.05
Holmes	Y	399318.9	5024681	206.25	8.13	1026.01
IvyAcres	Y	469749.1	5026352	521.75	7.25	93.23

Jordon	Y	465439.5	5023346	355.25	7.64	179.01
Kennedy	Y	436431.8	5028962	143.25	9.23	184.37
Lairg	Y	483646.2	5051871	183.00	7.20	108.66
Larose1	N - Larose forest land	488021.9	5026762	138.50	6.80	126.89
Larose2	N - Larose forest land	492926	4982061	233.00	7.33	127.68
Larose3	N - Larose forest land	401453.2	5010857	141.25	6.62	78.23
MacHardy	Y	507975.5	5006714	195.00	7.95	148.77
Malette	Y	467367.7	5043813	259.25	6.91	135.96
Navan	Y	468325.9	5003701	390.50	7.61	195.68
NoAdmittance	Y	424013.9	5042718	286.50	8.16	367.13
OldHazeldean	?	442600.2	4994452	727.00	7.64	584.54
PowerStation	Y	506519	4974219	455.00	7.99	156.20
Rheal	Y	444078.4	5018784	5.75	6.45	169.46
Schaubs	Y	444616.3	4970715	185.75	8.40	106.18
StAmour	?	453733.2	5037201	481.75	8.81	669.46
StoneySwamp*	N - National Capital Commission land	454168.5	4970809	320.25	7.7125	498.4466
StrawberryFields	Y	413068	5020560	185.00	8.37	160.59
TwoRocks	Y	478587	5043698	91.00	8.80	581.39
Vaughan	?	462300.2	5051372	368.25	8.03	182.75
Wilson	Y	462170.3	4987095	186.25	8.52	343.44

Chapter 2 Pond Information (continued). See Methods of Chapter 2 for more information. If a different number of survey transects was taken in 2005 than in 2006 (or if the distance between transects was different) then the 2006 results are in brackets. Differences between years were due to changes in pond size and the people conducting the survey.

Site	Average Emergent Vegetation (2005)	Average Floating Vegetation (2005)	Average Insolation (2006)	Proportion of shading of first 2 m of pond edge. (2006)	Number Of Transects	Distance Between Transects (m as measured by paces)
8thLine	24.58333	0	0.958333	0.166667	6	19
AbandonedFarm	22.1875	38.61111	0.375	0.833333	9(6)	?(57)
Bank	5.833333	0	0.833333	0.166667	6	38
Bilmer	33.00	13.50	0.71	0.00	5(7)	19(38)
Bouvier	32.50	0.00	0.79	0.33	6	19
Buckwheat	22.92	0.00	0.81	0.50	6(8)	76
Carbine	62.19	0.00	1.00	0.00	8	76
CercleDesErables	20.63	0.63	0.44	0.63	8	76
Ducks_Unlimited	59.38	13.44	1.00	0.00	8(12)	76
FrenchSettlement	12.92	10.00	0.10	1.00	6(5)	19
Galetta	20.41667	0	N/A	N/A	6(NA)	?(NA)
GatineauPark	42.19	2.19	1.00	0.00	8	76
Gibson's	21.00	0.00	0.92	0.17	5(6)	19
GoldenLine	11.67	0.00	0.85	0.40	6(5)	57
GravelPit	14.29	30.00	0.55	0.80	7(5)	38

Groulx	78.57	5.71	1.00	0.00	7(10)	57(38)
Holmes	20.00	50.00	0.33	0.88	4(16)	?(76)
IvyAcres	26.07	55.71	0.71	0.83	7(6)	19
Jordon	25.83	0.00	0.92	0.00	9(6)	38
Kennedy	21.94	0.00	1.00	0.00	9(6)	19(38)
Lairg	44.58	0.83	0.88	0.50	6(4)	38
Larose1	26.25	0.00	1.00	0.00	6(5)	19
Larose2	24.58	0.00	0.90	0.20	6(5)	19
Larose3	4.50	0.00	0.70	0.80	5	19
MacHardy	15.00	2.50	1.00	0.00	4(5)	38
Malette	33.33	20.00	1.00	0.00	6(4)	19(38)
Navan	28.44	1.25	1.00	0.00	8(5)	?(38)
NoAdmittance	42.27	0.00	0.86	0.14	11(7)	38(76)
OldHazeldean	13.27	0.00	0.92	0.22	13(9)	38(76)
PowerStation	14.64	47.14	0.50	0.75	7(4)	?(57)
Rheal	0.00	0.00	0.19	1.00	9(4)	19(57)
Schaubs	9.00	0.00	0.50	1.00	5(4)	19(38)
StAmour	46.56	1.25	0.55	0.45	8(11)	76
StoneySwamp	26.25	0	N/A	N/A	4(NA)	?(NA)
StrawberryFields	31.25	0.00	1.00	0.20	8(5)	19(38)
TwoRocks	15.68	0.00	0.48	0.90	11(10)	76
Vaughan	47.50	0.00	0.75	0.33	8(6)	19(38)
Wilson	7.86	0.00	0.42	0.83	8(6)	57(76)

Chapter 2 Raw data collected in 2005

NOTE: The data is arranged in several tables. 'Site' and 'Survey' are present in each table to allow the tables to be linked if required. Data are sorted by survey date.

Environmental Data - 2005

Survey - 1 to 8 - night surveys

v1 to v3 - visual day survey

d1 & d2 - day call survey (trials - not used in the analysis)

* indicates other surveys that were not used in the final analysis due to inclement weather during the survey.

Wind - Beaufort wind scale:

0	Calm	Calm, smoke rises vertically
1	Light Air	Smoke drift indicates wind direction, still wind vanes
2	Light Breeze	Wind felt on face, leaves rustle, vanes begin to move
3	Gentle Breeze	Leaves and small twigs constantly moving, light flags extended
4	Moderate Breeze	Dust, leaves, and loose paper lifted, small tree branches move
5	Fresh Breeze	Small trees in leaf begin to sway
6	Strong Breeze	Larger tree branches moving, whistling in wires
7	Near Gale	Whole trees moving, resistance felt walking against wind
8	Gale	Whole trees in motion, resistance felt walking against wind

Cloud

0	clear
1	partly cloudy or variable
2	cloudy or overcast
3	fog
4	drizzle
5	rain

Temp - Temperature in degrees Celsius.

Pondname	Survey	Date	Start Time	End Time	Wind	Cloud	Temp
StrawberryFields	1	12/04/2005	20:45	20:50	1	1	7
FrenchSettlement	1	12/04/2005	21:20	21:25	2	1	7
TwoRocks	1	12/04/2005	22:00	22:05	2	2	7
Buckwheat	1	12/04/2005	22:25	22:30	2	2	8
Kennedy	1	13/04/2005	20:35	20:40	1	0	7
Jordon	1	13/04/2005	21:00	21:10	1	0	7
Gibson's	1	13/04/2005	21:30	21:40	1	0	7
Holmes	1	13/04/2005	21:53	22:00	1	0	6
NoAdmittance	1	13/04/2005	22:20	22:28	1	0	6

Bouvier	1	14/04/2005	20:20	20:30	0	0	5
Rheal	1	14/04/2005	21:10	21:20	0	0	6
Groulx	1	14/04/2005	21:35	21:47	1	0	5
Ducks_Unlimited	1	14/04/2005	22:03	22:13	1	0	4
Malette	1	14/04/2005	22:20	22:30	1	0	4
Vaughan	1	14/04/2005	20:29	20:34	0	0	5
GoldenLine	1	14/04/2005	20:56	21:01	0	0	4
OldHazeldean	1	14/04/2005	21:29	21:34	0	0	4
StoneySwamp	1	14/04/2005	22:21	21:26	0	0	3
8thLine	1	15/04/2005	20:22	20:27	0	0	6
Navan	1	15/04/2005	20:43	20:48	0	0	6
Larose1	1	15/04/2005	21:20	21:25	0	0	5
Larose2	1	15/04/2005	21:35	21:40	0	0	5
Larose3	1	15/04/2005	22:00	22:07	0	0	4
Wilson	1	16/04/2005	20:30	20:39	1	0	13
GravelPit	1	16/04/2005	21:15	21:20	1	0	10
Bilmer	1	16/04/2005	21:35	21:40	1	0	10
MacHardy	1	16/04/2005	20:50	20:55	0	0	11
Galetta	1	16/04/2005	21:08	21:15	2	0	13
IvyAcres	1	16/04/2005	21:23	21:28	1	0	11
Carbine	1	16/04/2005	21:50	21:55	0	0	11
Lairg	1	17/04/2005	20:40	20:45	1	1	12
CercleDesErables	1	17/04/2005	21:20	21:25	1	1	14
GatineauPark	1	17/04/2005	22:13	22:18	1	0	12
StAmour	1	17/04/2005	23:10	23:15	1	0	11
PowerStation	1	17/04/2005	20:18	20:23	0	1	16
Schaubs	1	17/04/2005	20:46	20:51	0	1	14
Bank	1	17/04/2005	21:30	21:35	2	0	13
AbandonedFarm	1	17/04/2005	22:03	22:08	1	0	11
PowerStation	D1	18/04/2005	16:00	16:05	2	0	20
Schaubs	D1	18/04/2005	16:20	16:25	2	0	19
Bank	D1	18/04/2005	16:50	16:57	3	0	21
AbandonedFarm	D1	18/04/2005	17:10	17:15	4	0	20
StrawberryFields	D1	18/04/2005	15:00	15:05	2	0	19
FrenchSettlement	D1	18/04/2005	14:05	14:10	3	0	20
TwoRocks	D1	18/04/2005	15:30	15:35	3	0	20
Buckwheat	D1	18/04/2005	13:30	13:35	2	0	20
MacHardy	D1	19/04/2005	13:32		6	1	25
Galetta	D1	19/04/2005	13:45		6	0	26
IvyAcres	D1	19/04/2005	13:55		6	0	26
Carbine	D1	19/04/2005	14:18		6	0	26
Vaughan	2	23/04/2005	21:30	21:35	1	2	5
GoldenLine	2	23/04/2005	21:44	21:49	3	4	6
OldHazeldean	2	23/04/2005	21:14	21:19	3	4	5
StoneySwamp	2	23/04/2005	20:33	20:38	1	4	8
Bouvier	2	23/04/2005	21:56	22:02	1	2	6
Rheal	2	23/04/2005	21:21	21:27	5	2	5.5
Groulx	2	23/04/2005	21:02	21:11	6	5	5
Ducks_Unlimited	2	23/04/2005	20:35	20:44	5	4	6
Malette	2	23/04/2005	20:23	20:29	3	4	6

Wilson	2	22/04/2005	21:51	21:57	3	3	11
GravelPit	2	22/04/2005	21:13	21:18	2	3	11
Bilmer	2	22/04/2005	20:44	20:49	1	2	14
Kennedy	2	21/04/2005	21:36	21:45	1	0	3
Jordon	2	21/04/2005	21:15	21:27	1	0	4
Gibson's	2	21/04/2005	21:02	21:07	1	0	6
Holmes	2	21/04/2005	20:47	20:52	1	0	7
NoAdmittance	2	21/04/2005	20:31	20:38	1	0	7
8thLine	2	22/04/2005	22:19	20:25	0	2	10
Navan	2	22/04/2005	21:58	20:04	3	2	10.5
Larose1	2	22/04/2005	21:26	21:31	2	2	12
Larose2	2	22/04/2005	21:04	21:12	2	2	12
Larose3	2	22/04/2005	20:44	20:50	0	2	14
MacHardy	2	20/04/2005	22:05	22:10	3	0	4
Galetta	2	20/04/2005	21:45	21:51	3	0	4
IvyAcres	2	20/04/2005	21:35	21:40	2	0	6
Carbine	2	20/04/2005	21:05	21:10	1	0	5
StrawberryFields	2	21/04/2005	21:45	21:50	0	0	5
FrenchSettlement	2	21/04/2005	21:22	21:27	0	0	5
TwoRocks	2	21/04/2005	20:54	20:59	1	0	7
Buckwheat	2	21/04/2005	20:31	20:36	1	0	7
Lairg	2	20/04/2005	22:25	22:30	0	0	4
CercleDesErables	2	20/04/2005	22:00	22:05	1	0	4
GatineauPark	2	20/04/2005	21:20	21:25	0	0	2
StAmour	2	20/04/2005	20:27	20:33	0	1	6
PowerStation	2	20/04/2005	20:38		2	2	4
Schaubs	2	20/04/2005	20:55		0	1	4
Bank	2	20/04/2005	21:23		1	1	4
AbandonedFarm	2	20/04/2005	21:37		1	1	4
PowerStation	3	28/04/2005	21:11		1	4	6
Schaubs	3	28/04/2005	21:31		2	2	6
Bank	3	28/04/2005	20:30		2	5	6
AbandonedFarm	3	28/04/2005	20:45		2	2	6
MacHardy	3	28/04/2005	22:05	22:10	2	1	6
Galetta	3	28/04/2005	20:37	20:42	2	5	7
IvyAcres	3	28/04/2005	20:55	21:00	2	4	7
Carbine	3	28/04/2005	21:33	21:38	1	1	6
Lairg	3	28/04/2005	20:35	20:42	2	5	10
CercleDesErables	3	28/04/2005	21:55	22:02	4	1	7
GatineauPark	3	28/04/2005	22:45	22:50	2	3	7
StAmour	3	28/04/2005	21:10	21:18	1	4	8
Vaughan	3	29/04/2005	22:05	22:12	0	0	9
GoldenLine	3	29/04/2005	22:30	22:35	0	0	9
OldHazeldean	3	29/04/2005	20:38	20:44	2	2	13
StoneySwamp	3	29/04/2005	21:24	21:31	1	1	11
Kennedy	3	29/04/2005	21:38	21:44	1	1	6
Jordon	3	29/04/2005	21:52	21:57	1	1	7
Gibson's	3	29/04/2005	20:35	20:41	2	1	9
Holmes	3	29/04/2005	20:50	20:57	2	1	9
NoAdmittance	3	29/04/2005	21:05	21:11	2	1	7

StrawberryFields	3	30/04/2005	21:54	21:59	0	2	10
FrenchSettlement	3	30/04/2005	20:37	20:42	1	2	10
TwoRocks	3	30/04/2005	21:01	21:06	0	3	9
Buckwheat	3	30/04/2005	21:19	21:24	0	3	9.5
8thLine	3	30/04/2005	22:50	22:55	2	2	9
Navan	3	30/04/2005	20:37	20:43	2	3	11
Larose1	3	30/04/2005	21:15	21:20	1	3	9
Larose2	3	30/04/2005	21:30	21:35	1	2	9
Larose3	3	30/04/2005	22:00	22:05	1	2	9
Wilson	3	01/05/2005	22:11	22:16	3	0	7
GravelPit	3	01/05/2005	21:02	21:07	2	1	8
Bilmer	3	01/05/2005	21:26	21:31	2	0	8
Bouvier	3	01/05/2005	22:45	22:50	0	1	7
Rheal	3	01/05/2005	20:45	20:50	2	2	7
Groulx	3	01/05/2005	21:05	21:12	2	1	6
Ducks_Unlimited	3	01/05/2005	21:35	21:40	1	0	5
Malette	3	01/05/2005	21:55	22:00	0	0	4.5
PowerStation	v1	03/05/2005	13:05	13:25	4	2	7
Schaubs	v1	03/05/2005	13:40	13:55	4	2	7
Bank	v1	03/05/2005	14:10	14:25	4	2	7
AbandonedFarm	v1	03/05/2005	14:36	15:25	4	2	7
8thLine	v1	03/05/2005	12:44	13:12	2	2	8
Navan	v1	03/05/2005	13:46	14:16	1	2	9
Larose1	v1	03/05/2005	14:52	15:11	1	1	10
Larose2	v1	03/05/2005	15:25	15:44	5	1	11
Larose3	v1	03/05/2005	16:17	16:50	4	1	11
Bouvier	v1	04/05/2005	11:15	11:35	2	2	11
Rheal	v1	04/05/2005	12:05	12:25	2	2	8
Groulx	v1	04/05/2005	12:45	13:05	5	2	12
Ducks_Unlimited	v1	04/05/2005	13:30	14:20	5	2	11
Malette	v1	04/05/2005	14:30	14:45	3	1	12
Kennedy	v1	04/05/2005	11:37	12:00	3	1	11
Jordon	v1	04/05/2005	12:20	13:13	3	2	13
Gibson's	v1	04/05/2005	13:27	13:47	4	1	13
Holmes	v1	04/05/2005	14:00	15:10	4	2	14
NoAdmittance	v1	04/05/2005	15:20	16:00	3	2	13
PowerStation	4	04/05/2005	20:45	20:50	1	1	8
Schaubs	4	04/05/2005	21:00	21:05	2	1	8
Bank	4	04/05/2005	21:37	21:42	2	0	7
AbandonedFarm	4	04/05/2005	21:55	22:00	2	0	7
MacHardy	4	04/05/2005	21:00	21:05	0	1	8
Galetta	4	04/05/2005	21:40	21:45	0	1	9.5
IvyAcres	4	04/05/2005	21:25	21:30	0	1	8
Carbine	4	04/05/2005	22:05	22:10	0	1	8
Lairg	4	04/05/2005	20:45	20:50	0	1	8
CercleDesErables	4	04/05/2005	21:20	21:25	0	1	9
GatineauPark	4	04/05/2005	21:56	22:01	0	0	5
StAmour	4	04/05/2005	22:30	22:35	0	0	7
MacHardy	v1	05/05/2005	Unable to survey due to dog				
Galetta	v1	05/05/2005	10:56	11:14	1	1	16

IvyAcre	v1	05/05/2005	11:22	11:38	2	1	15
Carbine	v1	05/05/2005	12:02	12:24	2	1	13
Vaughan	v1	05/05/2005	10:37	11:07	0	1	15
GoldenLine	v1	05/05/2005	11:30	12:05	2	1	16
OldHazeldean	v1	05/05/2005	12:27	13:35	2	1	15.5
StoneySwamp	v1	05/05/2005	14:20	15:40	2	1	17
StrawberryFields	4	05/05/2005	20:45	20:50	0	1	13
FrenchSettlement	4	05/05/2005	21:15	21:20	0	0	12.5
TwoRocks	4	05/05/2005	21:45	21:50	0	0	13
Buckwheat	4	05/05/2005	22:06	22:13	0	0	12
Bouvier	4	05/05/2005	20:51	20:56	0	0	8
Rheal	4	05/05/2005	21:30	21:35	0	0	8
Groulx	4	05/05/2005	21:49	21:54	0	0	7
Ducks_Unlimited	4	05/05/2005	22:09	22:14	0	0	6
Malette	4	05/05/2005	22:26	22:31	0	0	5
Lairg	v1	06/05/2005	10:40	11:00	1	0	19
CercleDesErables	v1	06/05/2005	11:20	12:10	0	0	20
GatineauPark	v1	06/05/2005	12:40	13:30	3	0	21
StAmour	v1	06/05/2005	14:25	15:25	3	1	21
StrawberryFields	v1	06/05/2005	10:54	11:18	2	0	20
FrenchSettlement	v1	06/05/2005	11:38	11:56	1	1	19
TwoRocks	v1	06/05/2005	12:29	13:22	1	1	21
Buckwheat	v1	06/05/2005	13:37	13:54	1	1	21
Wilson	v1	06/05/2005	14:42	15:06	1	1	21
GravelPit	v1	06/05/2005	15:44	15:58	1	1	21
Bilmer	v1	06/05/2005	16:13	16:24	1	1	21
Vaughan	4	06/05/2005	20:52	20:57	1	0	14
GoldenLine	4	06/05/2005	21:09	21:14	1	0	11
OldHazeldean	4	06/05/2005	21:33	21:38	0	0	10
StoneySwamp	4	06/05/2005	22:07	22:12	0	0	9
Kennedy	4	06/05/2005	20:45	20:50	0	1	17
Jordon	4	06/05/2005	21:10	21:16	0	1	17
Gibson's	4	06/05/2005	21:30	21:38	0	1	17
Holmes	4	06/05/2005	21:50	21:55	0	0	16
NoAdmittance	4	06/05/2005	22:10	22:15	0	0	14
PowerStation	D2	07/05/2005	10:55	11:01	0	0	21.5
Schaubs	D2	07/05/2005	11:12	11:17	3	0	21
Bank	D2	07/05/2005	11:52	11:57	5	0	21
AbandonedFarm	D2	07/05/2005	12:11	12:16	4	0	24.5
Kennedy	D2	07/05/2005	12:51	12:56	6	0	22
Jordon	D2	07/05/2005	13:05	13:10	4	0	21
Gibson's	D2	07/05/2005	13:21	13:26	5	0	22.5
Holmes	D2	07/05/2005	13:36	13:41	4	0	22
NoAdmittance	D2	07/05/2005	13:54	13:59	5	1	21
8thLine	D2	07/05/2005	10:20	10:26	2	0	15
Navan	D2	07/05/2005	10:35	10:43	3	0	16
Larose1	D2	07/05/2005	11:05	11:12	2	0	16
Larose2	D2	07/05/2005	11:15	11:21	2	0	16
Larose3	D2	07/05/2005	11:30	11:36	2	0	18
Bouvier	D2	07/05/2005	13:00	13:06	2	0	19

Rheal	D2	07/05/2005	13:37	13:44	2	0	20
Groulx	D2	07/05/2005	14:05	14:10	6	1	20
Ducks_Unlimited	D2	07/05/2005	14:20	14:25	7	0	18
Malette	D2	07/05/2005	14:35	14:39	6	1	20
MacHardy	D2	05/05/2005	Unable to survey due to dog				
Galetta	D2	05/05/2005	10:56	11:14	1	1	16
IvyAcres	D2	05/05/2005	11:22	11:38	2	1	15
Carbine	D2	05/05/2005	12:02	12:24	2	1	13
Vaughan	D2	05/05/2005	10:37	11:07	0	1	15
GoldenLine	D2	05/05/2005	11:30	12:05	2	1	16
OldHazeldean	D2	05/05/2005	12:27	13:35	2	1	15.5
StoneySwamp	D2	05/05/2005	14:20	15:40	2	1	17
Lairg	D2	06/05/2005	10:40	11:00	1	0	19
CercleDesErables	D2	06/05/2005	11:20	12:10	0	0	20
GatineauPark	D2	06/05/2005	12:40	13:30	3	0	21
StAmour	D2	06/05/2005	14:25	15:25	3	1	21
StrawberryFields	D2	06/05/2005	10:54	11:18	2	0	20
FrenchSettlement	D2	06/05/2005	11:38	11:56	1	1	19
TwoRocks	D2	06/05/2005	12:29	13:22	1	1	21
Buckwheat	D2	06/05/2005	13:37	13:54	1	1	21
Wilson	D2	06/05/2005	14:42	15:06	1	1	21
GravelPit	D2	06/05/2005	15:44	15:58	1	1	21
Bilmer	D2	06/05/2005	16:13	16:24	1	1	21
8thLine	4	07/05/2005	20:44	20:50	0	0	14
Navan	4	07/05/2005	21:00	21:05	1	0	12
Larose1	4	07/05/2005	21:27	21:33	1	0	12
Larose2	4	07/05/2005	21:35	21:41	2	0	12
Larose3	4	07/05/2005	21:53	21:58	1	0	12
Wilson	4	07/05/2005	20:50	20:56	3	0	13
GravelPit	4	07/05/2005	21:25	21:31	6	0	12
Bilmer	4	07/05/2005	21:50	21:55	4	0	12
PowerStation	5	16/05/2005	22:10	22:16	2	2	9
Schaubs	5	16/05/2005	21:54	22:00	4	2	9
Bank	5	16/05/2005	21:20	21:26	1	2	9
AbandonedFarm	5	16/05/2005	20:57	21:03	4	1	9
MacHardy	5	16/05/2005	22:15	22:10	0	1	14
Galetta	5	16/05/2005	21:55	22:00	0	1	14
IvyAcres	5	16/05/2005	21:40	21:45	0	1	13
Carbine	5	16/05/2005	21:10	21:15	0	1	14
Lairg	5	16/05/2005	23:00	23:05	0	1	8
CercleDesErables	5	16/05/2005	22:17	22:22	0	1	8
GatineauPark	5	16/05/2005	21:39	21:44	1	1	8
StAmour	5	16/05/2005	21:00	21:05	0	1	11
Kennedy	5	17/05/2005	21:44	21:49	0	2	10
Jordon	5	17/05/2005	21:40	21:45	1	2	12
Gibson's	5	17/05/2005	21:27	21:32	1	2	12
Holmes	5	17/05/2005	21:14	21:19	1	2	12
NoAdmittance	5	17/05/2005	21:01	21:06	1	1	11
StrawberryFields	5	17/05/2005	22:15	22:20	1	2	9
FrenchSettlement	5	17/05/2005	21:55	22:00	0	2	8

TwoRocks	5	17/05/2005	21:30	21:35	0	2	8
Buckwheat	5	17/05/2005	21:05	21:11	0	2	9
8thLine	5	18/05/2005	22:28	22:33	0	0	5
Navan	5	18/05/2005	22:08	22:13	0	0	4
Larose1	5	18/05/2005	21:43	21:48	0	1	6
Larose2	5	18/05/2005	21:25	21:30	0	3	7
Larose3	5	18/05/2005	21:03	21:08	0	1	7
Wilson	5	18/05/2005	22:00	22:07	0	0	13
GravelPit	5	18/05/2005	21:27	21:32	0	0	10
Bilmer	5	18/05/2005	21:05	21:10	0	1	10
Bouvier	5	19/05/2005	22:33	22:38	1	1	8
Rheal	5	19/05/2005	22:01	22:06	1	1	10
Groulx	5	19/05/2005	21:44	21:49	1	1	14
Ducks_Unlimited	5	19/05/2005	21:20	21:25	1	1	12
Malette	5	19/05/2005	21:08	21:13	1	1	14
Vaughan	5	19/05/2005	22:20	22:25	0	0	8
GoldenLine	5	19/05/2005	22:00	22:05	0	0	10
OldHazeldean	5	19/05/2005	21:35	21:40	0	0	12
StoneySwamp	5	19/05/2005	21:00	21:05	0	0	12
8thLine	v2	24/05/2005	14:00	14:30	4	1	16
Navan	v2	24/05/2005	13:20	13:50	4	1	16
Larose1	v2	24/05/2005	12:22	12:47	4	1	16
Larose2	v2	24/05/2005	11:50	12:12	6	1	16
Larose3	v2	24/05/2005	11:10	11:35	3	1	16
Wilson	v2*	24/05/2005	11:35	11:55	6	1	16
GravelPit	v2*	24/05/2005	12:05	12:25	6	1	16
Bilmer	v2*	24/05/2005	13:05	13:30	5	1	16
StrawberryFields	v2	25/05/2005	13:00	13:14	4	0	22
FrenchSettlement	v2	25/05/2005	12:35	12:45	3	0	22
TwoRocks	v2	25/05/2005	11:20	12:10	3	0	21
Buckwheat	v2	25/05/2005	10:40	11:10	4	0	21
PowerStation	v2	25/05/2005	15:05	15:25	3	0	33
Schaubs	v2	25/05/2005	14:55	15:05	3	0	24
Bank	v2	25/05/2005	14:25	14:38	5	0	27
AbandonedFarm	v2	25/05/2005	13:40	14:15	4	0	26
Lairg	v2	25/05/2005	15:20	15:44	1	0	20+
CercleDesErables	v2	25/05/2005	14:27	14:59	2	0	20+
GatineauPark	v2	25/05/2005	12:30	13:40	3	0	20+
StAmour	v2	25/05/2005	10:30	11:55	3	0	20+
MacHardy	v2	26/05/2005	18:40	19:00	2	1	20
Galetta	v2	26/05/2005	11:25	11:50	1	1	23
IvyAcres	v2	26/05/2005	10:55	11:21	1	1	26
Carbine	v2	26/05/2005	10:25	10:40	1	1	23
Kennedy	v2	26/05/2005	15:30	15:45	4	2	23?
Jordon	v2	26/05/2005	14:40	14:45	4	2	23?
Gibson's	v2	26/05/2005	13:57	14:07	4	1	23?
Holmes	v2	26/05/2005	11:50	13:05	5	1	23?
NoAdmittance	v2	26/05/2005	10:40	11:30	5	1	23?
Vaughan	v2*	27/05/2005	13:40	14:00	1	1	19
GoldenLine	v2*	27/05/2005	13:05	13:30	1	4	15

OldHazeldean	v2*	27/05/2005	12:00	12:45	1	2	17
StoneySwamp	v2*	27/05/2005	10:30	11:20	1	2	17
Bouvier	v2*	27/05/2005	14:15	14:25	0	4	15+
Rheal	v2*	27/05/2005	13:24	13:37	0	2	15+
Groulx	v2*	27/05/2005	12:24	13:04	0	2	15+
Ducks_Unlimited	v2*	27/05/2005	11:43	12:05	0	2	15+
Malette	v2*	27/05/2005	11:21	11:30	0	2	15+
Vaughan	v2	29/05/2005	13:35	14:00	1	1	26
GoldenLine	v2	29/05/2005	13:05	13:25	1	1	25
OldHazeldean	v2	29/05/2005	12:00	12:45	1	1	23
StoneySwamp	v2	29/05/2005	10:20	11:10	1	1	21
Wilson	v2	29/05/2005	16:15	16:33	3	5	17
GravelPit	v2	29/05/2005	15:33	15:44	1	2	19
Bilmer	v2	29/05/2005	15:02	15:12	2	4	19
Bouvier	v2	29/05/2005	13:28	13:38	2	1	22
Rheal	v2	29/05/2005	12:35	12:53	2	1	21
Groulx	v2	29/05/2005	11:25	12:09	0	1	20
Ducks_Unlimited	v2	29/05/2005	10:48	11:07	0	0	19
Malette	v2	29/05/2005	10:30	10:39	0	0	18
PowerStation	6	30/05/2005	21:35	21:40	0	1	14
Schaubs	6	30/05/2005	21:17	21:22	0	1	13
Bank	6	30/05/2005	22:27	22:32	0	1	16
AbandonedFarm	6	30/05/2005	22:04	22:09	1	1	16
MacHardy	6	30/05/2005	21:42	21:47	1	1	14
Galetta	6	30/05/2005	21:26	21:32	1	1	15
IvyAcres	6	30/05/2005	22:30	22:36:00	0	1	14
Carbine	6	30/05/2005	22:09	22:15	0	0	12
Lairg	6	30/05/2005	22:25	22:30	0	1	15?
CercleDesErables	6	30/05/2005	21:56	21:01	0	1	15?
GatineauPark	6	30/05/2005	21:18	21:23	0	1	15?
StAmour	6	30/05/2005	22:56	23:01	0	0	15?
Vaughan	6	31/05/2005	22:15	22:20	0	1	19
GoldenLine	6	31/05/2005	21:59	22:04	0	1	18
OldHazeldean	6	31/05/2005	23:25	23:30	1	1	18
StoneySwamp	6	31/05/2005	22:45	22:50	0	1	18
Bouvier	6	31/05/2005	22:37	22:42	0	1	15
Rheal	6	31/05/2005	22:00	22:05	0	0	16
Groulx	6	31/05/2005	21:23	21:29	0	1	17
Ducks_Unlimited	6	31/05/2005	23:40	23:45	1	0	12
Malette	6	31/05/2005	23:20	23:25	1	0	15
StrawberryFields	6	01/06/2005	21:37	21:42	0	1	19
FrenchSettlement	6	01/06/2005	21:20	21:25	0	1	19
TwoRocks	6	01/06/2005	22:24	22:29	0	0	18
Buckwheat	6	01/06/2005	22:09	22:15	0	0	19
Kennedy	6	01/06/2005	21:53	21:58	0	0	18
Jordon	6	01/06/2005	21:34	21:39	0	1	19
Gibson's	6	01/06/2005	21:16	21:22	0	1	22
Holmes	6	01/06/2005	22:45	22:50	0	0	17
NoAdmittance	6	01/06/2005	22:30	22:35	0	0	18
8thLine	6	02/06/2005	22:15	22:20	1	0	19

Navan	6	02/06/2005	21:52	21:57	1	1	21
Larose1	6	02/06/2005	21:20	21:25	1	1	21
Larose2	6	02/06/2005	23:07	23:12	1	0	19
Larose3	6	02/06/2005	22:55	23:00	1	0	18
Wilson	6	02/06/2005	21:55	22:00	0	1	19
GravelPit	6	02/06/2005	21:25	21:30	0	2	18
Bilmer	6	02/06/2005	22:20	22:35	0	0	18
8thLine	7	13/06/2005	21:21	21:26	0	2	25
Navan	7	13/06/2005	21:38	21:42	0	2	26
Larose1	7	13/06/2005	22:05	22:10	0	2	26
Larose2	7	13/06/2005	22:15	22:20	0	2	26
Larose3	7	13/06/2005	22:32	22:37	0	2	27
Wilson	7	13/06/2005	21:28	21:34	1	2	26
GravelPit	7	13/06/2005	21:58	22:03	0	2	26
Bilmer	7	13/06/2005	22:16	22:21	1	4	25
MacHardy	7	14/06/2005	21:10	21:15	2	0	25
Galetta	7	14/06/2005	21:25	21:30	2	1	25
IvyAcres	7	14/06/2005	21:35	21:40	1	1	25
Carbine	7	14/06/2005	21:56	22:01	2	1	25
Lairg	7	14/06/2005	12:30	21:35	0	1	24
CercleDesErables	7	14/06/2005	21:48	21:53	0	0	22
GatineauPark	7	14/06/2005	22:15	22:20	0	0	22
StAmour	7	14/06/2005	22:47	22:52	4	2	23
PowerStation	7	14/06/2005	21:25	21:30	1	1	23?
Schaubs	7	14/06/2005	21:38	21:43	1	1	23?
Bank	7	14/06/2005	22:14	22:19	1	1	23?
AbandonedFarm	7	14/06/2005	22:35	22:40	1	2	23?
Vaughan	7	15/06/2005	21:31	21:36	2	1	20
GoldenLine	7	15/06/2005	21:56	22:01	2	2	20
OldHazeldean	7	15/06/2005	22:22	22:27	3	2	20
StoneySwamp	7	15/06/2005	22:55	23:00	1	2	18
Bouvier	7	15/06/2005	21:26	21:31	2	2	18
Rheal	7	15/06/2005	21:59	22:04	3	4	16
Groulx	7	15/06/2005	22:17	22:22	1	2	16
Ducks_Unlimited	7	15/06/2005	22:37	22:42	4	4	16
Malette	7	15/06/2005	22:50	22:55	1	4	16
StrawberryFields	7	16/06/2005	21:18	21:23	1	4	15
FrenchSettlement	7	16/06/2005	21:39	21:44	1	1	16
TwoRocks	7	16/06/2005	22:03	22:08	1	1	15
Buckwheat	7	16/06/2005	22:21	22:26	1	1	16
Kennedy	7	16/06/2005	21:24	21:29	0	4	18
Jordon	7	16/06/2005	21:40	21:45	0	4	18
Gibson's	7	16/06/2005	21:55	22:00	1	1	18
Holmes	7	16/06/2005	22:09	22:14	1	1	18
NoAdmittance	7	16/06/2005	22:23	22:28	0	1	17
PowerStation	v3	04/07/2005	17:09	17:30	3	1	>25
Schaubs	v3	04/07/2005	17:42	17:52	4	1	>25
Bank	v3	04/07/2005	15:08	15:32	5	1	>25
AbandonedFarm	v3	04/07/2005	15:55	16:36	5	1	>25
StrawberryFields	v3	04/07/2005	13:58	14:10	3	1	>25

FrenchSettlement	v3	04/07/2005	14:26	14:35	2	1	>25
TwoRocks	v3	04/07/2005	11:57	12:54	3	0	>25
Buckwheat	v3	04/07/2005	13:07	13:31	2	0	>25
Lairg	v3	06/07/2005	11:16	11:33	0	1	20?
CercleDesErables	v3	06/07/2005	11:50	12:30	2	1	20?
GatineauPark	v3	05/07/2005	11:42	12:40	2	2	20-25
StAmour	v3	05/07/2005	13:14	14:46	3	4	20-25
8thLine	v3	08/07/2005	11:54	12:07	1	2	23
Navan	v3	08/07/2005	12:19	12:48	2	1	24
Larose1	v3	08/07/2005	09:56	10:13	1	1	22
Larose2	v3	08/07/2005	10:19	10:32	2	1	22
Larose3	v3	08/07/2005	10:45	11:03	1	1	22
Wilson	v3	08/07/2005	14:53	15:09	1	2	24
GravelPit	v3	08/07/2005	13:45	13:54	1	2	24
Bilmer	v3	08/07/2005	14:11	14:20	1	2	24
MacHardy	v3	07/07/2005	17:06	17:25	2	0	27
Galetta	v3	07/07/2005	16:28	16:40	2	0	27
IvyAcres	v3	07/07/2005	15:20	15:33	2	0	26
Carbine	v3	07/07/2005	15:48	16:10	2	0	25
Vaughan	v3	07/07/2005	13:40	14:02	1	0	26
GoldenLine	v3	07/07/2005	14:18	14:40	2	1	26
OldHazeldean	v3	07/07/2005	10:13	11:12	3	0	24
StoneySwamp	v3	07/07/2005	12:02	12:48	2	0	26
Bouvier	v3	11/07/2005	10:32	10:46	1	0	28
Rheal	v3	11/07/2005	14:11	14:38	1	0	35
Groulx	v3	11/07/2005	11:31	12:07	2	0	32
Ducks_Unlimited	v3	11/07/2005	12:32	13:27	2	0	33
Malette	v3	11/07/2005	13:37	13:48	4	0	34
Kennedy	v3	12/07/2005	13:38	13:57	1	0	31
Jordon	v3	12/07/2005	14:00	14:20	2	1	31
Gibson's	v3	12/07/2005	09:55	10:09	2	0	27
Holmes	v3	12/07/2005	10:26	12:14	2	0	28
NoAdmittance	v3	12/07/2005	12:42	13:05	1	0	31
StrawberryFields	8	18/07/2005	22:26	22:31	1	1	26
FrenchSettlement	8	18/07/2005	22:08	22:13	1	1	27
TwoRocks	8	18/07/2005	21:45	21:50	1	2	27
Buckwheat	8	18/07/2005	21:29	21:34	1	2	27
Kennedy	8	18/07/2005	22:29	22:34	3	1	26
Jordon	8	18/07/2005	22:14	22:19	3	1	25
Gibson's	8	18/07/2005	22:00	22:05	4	1	25
Holmes	8	18/07/2005	21:45	21:50	3	1	26
NoAdmittance	8	18/07/2005	21:28	21:33	4	1	26
Vaughan	8	19/07/2005	22:24	22:29	0	1	>20
GoldenLine	8	19/07/2005	22:09	22:14	0	1	>20
OldHazeldean	8	19/07/2005	21:48	21:53	0	1	>20
StoneySwamp	8	19/07/2005	21:15	21:20	0	0	>20
Bouvier	8	19/07/2005	22:53	22:58	2	1	22
Rheal	8	19/07/2005	22:15	22:20	0	1	22
Groulx	8	19/07/2005	21:54	21:59	2	1	24
Ducks_Unlimited	8	19/07/2005	21:33	21:38	2	1	24

Malette	8	19/07/2005	21:19	21:24	2	1	24
Wilson	8	20/07/2005	22:29	22:34	0	1	21
GravelPit	8	20/07/2005	22:01	22:06	0	0	19
Bilmer	8	20/07/2005	21:41	21:46	0	0	20
8thLine	8	20/07/2005	22:19	22:24	0	0	18
Navan	8	20/07/2005	22:05	22:10	0	0	20
Larose1	8	20/07/2005	21:42	21:47	0	0	20
Larose2	8	20/07/2005	21:30	21:35	0	0	>20
Larose3	8	20/07/2005	21:12	21:17	0	0	24
MacHardy	8	21/07/2005	21:56	22:01	0	1	22
Galetta	8	21/07/2005	21:43	21:48	1	1	22
IvyAcres	8	21/07/2005	21:34	21:39	0	1	22
Carbine	8	21/07/2005	21:14	21:19	0	1	22
Lairg	8	21/07/2005	22:30	22:35	0	0	<20
CercleDesErables	8	21/07/2005	22:12	22:17	0	0	<20
GatineauPark	8	21/07/2005	21:46	21:51	3	0	<20
StAmour	8	21/07/2005	21:14	21:19	0	1	23
PowerStation	8	21/07/2005	22:03	22:08	1	1	<20
Schaubs	8	21/07/2005	21:51	21:56	1	1	<20
Bank	8	21/07/2005	21:28	21:33	1	1	<20
AbandonedFarm	8	21/07/2005	21:15	21:20	1	1	<20

2005 Field Data - Call Surveys - Calling directly at pond

NOTE: D1 and D2 not used in the analysis

Species are: Species: WDF = Wood frog, WCF = Western chorus frog; SPP = Spring peeper; NLF = Northern leopard frog; AMT = American toad; GTF = Gray treefrog; GRF = Green frog; MIF = Mink frog; BUF = Bull frog.

Calling activity for each species

- 0** no individuals calling
- 1** individual(s) can be counted, calls are not overlapping
- 2** calls of <15 individuals can be distinguished, but there is some overlapping
- 3** calls of ≥ 15 individuals

Pondname	Survey	WDF	WCF	SPP	AMT	NLF	GTF	GRF	BUF
StrawberryFields	1	1							
FrenchSettlement	1								
TwoRocks	1		1						
Buckwheat	1	1				1			
Kennedy	1								
Jordon	1								
Gibson's	1								
Holmes	1	2		1					
NoAdmittance	1			1		1			
Bouvier	1			1					
Rheal	1	1		1					
Groulx	1								
Ducks_Unlimited	1								
Malette	1								
Vaughan	1								
GoldenLine	1		1						
OldHazeldean	1		1						
StoneySwamp	1	1	2	3					
8thLine	1								
Navan	1								
Larose1	1								
Larose2	1								
Larose3	1								
Wilson	1								
GravelPit	1	1							
Bilmer	1	2		3					
MacHardy	1								
Galetta	1								
IvyAcres	1	1							
Carbine	1								
Lairg	1			1					
CercleDesErables	1			1					

GatineauPark	1			2					
StAmour	1	1		1					
PowerStation	1								
Schaubs	1								
Bank	1								
AbandonedFarm	1	1		2		1			
Vaughan	2			1					
GoldenLine	2		1	1					
OldHazeldean	2		1	1					
StoneySwamp	2	1		3		1			
Bouvier	2		1	2					
Rheal	2	1	1	3					
Groulx	2			1					
Ducks_Unlimited	2			3					
Malette	2								
Wilson	2			1					
GravelPit	2			2					
Bilmer	2	1		3					
Kennedy	2								
Jordon	2					1?			
Gibson's	2								
Holmes	2	2		3		1?			
NoAdmittance	2	1		3					
8thLine	2			1					
Navan	2					1			
Larose1	2			1		1			
Larose2	2								
Larose3	2	1		2					
MacHardy	2								
Galetta	2								
IvyAcres	2								
Carbine	2			1					
StrawberryFields	2			2					
FrenchSettlement	2	1		3					
TwoRocks	2			3		1			
Buckwheat	2			3		1			
Lairg	2			1					
CercleDesErables	2			1					
GatineauPark	2			3					
StAmour	2			3					
PowerStation	2						1		
Schaubs	2			1					
Bank	2								
AbandonedFarm	2	1		1					
PowerStation	3			1		1			
Schaubs	3								
Bank	3								
AbandonedFarm	3			3		1			

MacHardy	3			1					
Galetta	3								
IvyAcres	3								
Carbine	3			3					
Lairg	3			1					
CercleDesErables	3			2					
GatineauPark	3			3					
StAmour	3			3					
Vaughan	3								
GoldenLine	3			2					
OldHazeldean	3								
StoneySwamp	3			3		2			
Kennedy	3								
Jordon	3					1			
Gibson's	3								
Holmes	3			2		1			
NoAdmittance	3			2					
StrawberryFields	3			2		1			
FrenchSettlement	3	1		3					
TwoRocks	3			3					
Buckwheat	3			3					
8thLine	3			1					
Navan	3			2					
Larose1	3			3					
Larose2	3								
Larose3	3			2					
Wilson	3								
GravelPit	3			3					
Bilmer	3			3					
Bouvier	3			2					
Rheal	3			3					
Groulx	3			1		1			
Ducks_Unlimited	3								
Malette	3			3		1			
PowerStation	4			1					
Schaubs	4								
Bank	4								
AbandonedFarm	4			3		1			
MacHardy	4								
Galetta	4		1		1				
IvyAcres	4								
Carbine	4			1					
Lairg	4								
CercleDesErables	4			1					
GatineauPark	4			3					
StAmour	4			1					
StrawberryFields	4			2					
FrenchSettlement	4			3					

TwoRocks	4			2					
Buckwheat	4			3		1			
Bouvier	4			3	1				
Rheal	4			3			1		
Groulx	4			1	1				
Ducks_Unlimited	4	1				1			
Malette	4			2		1			
Vaughan	4			2					
GoldenLine	4			3					
OldHazeldean	4								
StoneySwamp	4			3		2			
Kennedy	4								
Jordon	4				1	1		1	
Gibson's	4					1			
Holmes	4			3	2	2			
NoAdmittance	4			2		1			
8thLine	4			2					
Navan	4			2	1	1			
Larose1	4			3		2			
Larose2	4								
Larose3	4			3		1			
Wilson	4				2				
GravelPit	4			3	2				
Bilmer	4			3	2				
PowerStation	5					1			
Schaubs	5								
Bank	5								
AbandonedFarm	5			3		1			
MacHardy	5								
Galetta	5								
IvyAcres	5								
Carbine	5			2					
Lairg	5			1					
CercleDesErables	5			3					
GatineauPark	5			3					
StAmour	5			3				1	
Kennedy	5								
Jordon	5								
Gibson's	5								
Holmes	5			2		1			
NoAdmittance	5			2		1			
StrawberryFields	5			2					
FrenchSettlement	5			3					
TwoRocks	5			3					
Buckwheat	5			3		1			
8thLine	5			1					
Navan	5			2		1			
Larose1	5			2		1			

Larose2	5			1					
Larose3	5			2					
Wilson	5								
GravelPit	5			3					
Bilmer	5			3					
Bouvier	5			2					
Rheal	5			3					
Groulx	5			2		1			
Ducks_Unlimited	5					1			
Malette	5			3		1			
Vaughan	5			1					
GoldenLine	5			1					
OldHazeldean	5								
StoneySwamp	5			3					
PowerStation	6			1				1	
Schaubs	6								
Bank	6								
AbandonedFarm	6			2	1		3	1	
MachHardy	6								
Galetta	6								
IvyAcres	6							1	
Carbine	6								
Lairg	6							1	
CercleDesErables	6			1					
GatineauPark	6			3					
StAmour	6			2			1	1	
Vaughan	6			2				1	
GoldenLine	6			2			3	1	
OldHazeldean	6			1				1	
StoneySwamp	6							2	
Bouvier	6						2	1	
Rheal	6			2			2		
Groulx	6			1				1	
Ducks_Unlimited	6					1			
Malette	6			1					
StrawberryFields	6			2			3		
FrenchSettlement	6			2			2		
TwoRocks	6						3		
Buckwheat	6			3			3	1	
Kennedy	6						3		
Jordon	6							1	
Gibson's	6					1		1	
Holmes	6						3	1	
NoAdmittance	6						1		
8thLine	6			1			1	1	
Navan	6			1	1	1	2	1	
Larose1	6							1	
Larose2	6							1	

Larose3	6			1	1		1	1	
Wilson	6								
GravelPit	6			1	1		1	1	
Bilmer	6			1			2	1	
8thLine	7							1	
Navan	7						2	1	
Larose1	7								1
Larose2	7								
Larose3	7								
Wilson	7								
GravelPit	7						2	1	
Bilmer	7						3		
MacHardy	7						1		
Galetta	7								
IvyAcres	7						2	1	
Carbine	7						1	1	
Lairg	7							1	
CercleDesErables	7			3			3	1	1
GatineauPark	7			1			3	1	
StAmour	7						3	1	
PowerStation	7			1					
Schaubs	7								
Bank	7						1	1	
AbandonedFarm	7						2	1	
Vaughan	7						1		
GoldenLine	7						3	1	
OldHazeldean	7						3	1	
StoneySwamp	7						3	1	
Bouvier	7						1	1	
Rheal	7								
Groulx	7			1					
Ducks_Unlimited	7								
Malette	7			3	1				
StrawberryFields	7						2	1	
FrenchSettlement	7								
TwoRocks	7							1	
Buckwheat	7						1	1	
Kennedy	7						2	1	
Jordon	7							1	1
Gibson's	7							1	
Holmes	7						1	1	
NoAdmittance	7							1	
StrawberryFields	8						1		
FrenchSettlement	8							1	
TwoRocks	8							1	
Buckwheat	8							1	
Kennedy	8							1	
Jordon	8				1		2	2	

Gibson's	8						2	
Holmes	8					2	1	
NoAdmittance	8						1	1
Vaughan	8						2	
GoldenLine	8						1	
OldHazeldean	8						1	
StoneySwamp	8						1	
Bouvier	8						2	
Rheal	8						2	
Groulx	8						1	
Ducks_Unlimited	8							
Malette	8						1	
Wilson	8							
GravelPit	8						1	
Bilmer	8						1	
8thLine	8						1	
Navan	8						2	
Larose1	8						2	1
Larose2	8						1	
Larose3	8						2	
MacHardy	8							
Galetta	8						1	
IvyAcres	8						1	
Carbine	8							
Lairg	8						1	
CercleDesErables	8						1	1
GatineauPark	8						1	
StAmour	8						2	1
PowerStation	8							
Schaubs	8							
Bank	8					1	1	
AbandonedFarm	8						1	
PowerStation	D1					1		
Schaubs	D1							
Bank	D1							
AbandonedFarm	D1					2		
StrawberryFields	D1							
FrenchSettlement	D1	3		1				
TwoRocks	D1							
Buckwheat	D1							
MacHardy	D1							
Galetta	D1							
IvyAcres	D1	1						
Carbine	D1							
PowerStation	D2							
Schaubs	D2							
Bank	D2							
AbandonedFarm	D2				2	1		

Kennedy	D2								
Jordon	D2				2			1	
Gibson's	D2								
Holmes	D2					1			
NoAdmittance	D2								
8thLine	D2			1					
Navan	D2					2			
Larose1	D2					1			
Larose2	D2								
Larose3	D2								
Bouvier	D2				2				
Rheal	D2								
Groulx	D2					1			
Ducks_Unlimited	D2					1			
Malette	D2					1			
MacHardy	D2								
Galetta	D2								
IvyAcres	D2								
Carbine	D2								
Vaughan	D2								
GoldenLine	D2								
OldHazeldean	D2								
StoneySwamp	D2					3			
Lairg	D2								
CercleDesErables	D2								
GatineauPark	D2								
StAmour	D2								
StrawberryFields	D2								
FrenchSettlement	D2								
TwoRocks	D2								
Buckwheat	D2								
Wilson	D2								
GravelPit	D2								
Bilmer	D2								

2005 Field Data - Evening Call Surveys -Calling within 100 m of the pond edge

NOTE: D1 and D2 not used in the analysis

Species are: Species: WDF = Wood frog, WCF = Western chorus frog; SPP = Spring peeper; NLF = Northern leopard frog; AMT = American toad; GTF = Gray treefrog; GRF = Green frog; MIF = Mink frog; BUF = Bull frog.

Calling activity for each species

- 0 no individuals calling
- 1 individual(s) can be counted, calls are not overlapping
- 2 calls of <15 individuals can be distinguished, but there is some overlapping
- 3 calls of ≥ 15 individuals

Pondname	Survey	WDF	WCF	SPP	AMT	NLF	GTF	GRF	BUF
StrawberryFields	1								
FrenchSettlement	1			1					
TwoRocks	1			1					
Buckwheat	1			1					
Kennedy	1	1							
Jordon	1	1						1	
Gibson's	1								
Holmes	1								
NoAdmittance	1								
Bouvier	1	2		3					
Rheal	1								
Groulx	1								
Ducks_Unlimited	1								
Malette	1								
Vaughan	1			1					
GoldenLine	1		2	1					
OldHazeldean	1	1	1	1					
StoneySwamp	1								
8thLine	1								
Navan	1								
Larose1	1	2							
Larose2	1	1							
Larose3	1	2							
Wilson	1								
GravelPit	1								
Bilmer	1								
MacHardy	1								
Galetta	1								
IvyAcres	1								
Carbine	1			1					
Lairg	1								
CercleDesErables	1	2							
GatineauPark	1	1							
StAmour	1								
PowerStation	1	1							
Schaubs	1			2					
Bank	1								
AbandonedFarm	1								
Vaughan	2			3					
GoldenLine	2		2	1					
OldHazeldean	2		1	2					
StoneySwamp	2	2							
Bouvier	2	1		3					
Rheal	2								
Groulx	2								
Ducks_Unlimited	2								
Malette	2								
Wilson	2			1					
GravelPit	2	1							
Bilmer	2								
Kennedy	2			1					
Jordon	2								

Gibson's	2								
Holmes	2								
NoAdmittance	2								
8thLine	2								
Navan	2	1		1					
Larose1	2			2		1			
Larose2	2	1		2					
Larose3	2	1							
MacHardy	2								
Galetta	2	1							
IvyAcres	2								
Carbine	2								
StrawberryFields	2	1							
FrenchSettlement	2								
TwoRocks	2								
Buckwheat	2								
Lairg	2								
CercleDesErables	2			2					
GatineauPark	2								
StAmour	2								
PowerStation	2								
Schaubs	2			1					
Bank	2								
AbandonedFarm	2								
PowerStation	3								
Schaubs	3								
Bank	3								
AbandonedFarm	3								
MacHardy	3								
Galetta	3								
IvyAcres	3								
Carbine	3								
Lairg	3			1					
CercleDesErables	3			3					
GatineauPark	3								
StAmour	3								
Vaughan	3			2					
GoldenLine	3								
OldHazeldean	3		1	3					
StoneySwamp	3								
Kennedy	3								
Jordon	3								
Gibson's	3								
Holmes	3								
NoAdmittance	3								
StrawberryFields	3								
FrenchSettlement	3								
TwoRocks	3								
Buckwheat	3								
8thLine	3								
Navan	3								
Larose1	3								
Larose2	3								
Larose3	3	1							
Wilson	3								

GravelPit	3								
Bilmer	3								
Bouvier	3				2				
Rheal	3								
Groulx	3								
Ducks_Unlimited	3								
Malette	3								
PowerStation	4								
Schaubs	4								
Bank	4			2					
AbandonedFarm	4								
MacHardy	4								
Galetta	4								
IvyAcres	4								
Carbine	4								
Lairg	4								
CercleDesErables	4			2					
GatineauPark	4								
StAmour	4								
StrawberryFields	4								
FrenchSettlement	4								
TwoRocks	4			3					
Buckwheat	4								
Bouvier	4								
Rheal	4								
Groulx	4								
Ducks_Unlimited	4	1		3	1	2			
Malette	4								
Vaughan	4			3					
GoldenLine	4				1				
OldHazeldean	4		3	3					
StoneySwamp	4								
Kennedy	4								
Jordon	4								
Gibson's	4								
Holmes	4								
NoAdmittance	4								
8thLine	4								
Navan	4			2	3				
Larose1	4			3					
Larose2	4			3	2				
Larose3	4				3				
Wilson	4								
GravelPit	4								
Bilmer	4								
PowerStation	5			1					
Schaubs	5								
Bank	5								
AbandonedFarm	5								
MacHardy	5								
Galetta	5								
IvyAcres	5								
Carbine	5								
Lairg	5								
CercleDesErables	5								

GatineauPark	5								
StAmour	5								
Kennedy	5			1					
Jordon	5								
Gibson's	5								
Holmes	5								
NoAdmittance	5								
StrawberryFields	5								
FrenchSettlement	5								
TwoRocks	5								
Buckwheat	5								
8thLine	5								
Navan	5								
Larose1	5			3					
Larose2	5			3					
Larose3	5			3					
Wilson	5								
GravelPit	5								
Bilmer	5								
Bouvier	5			2	1				
Rheal	5			3					
Groulx	5								
Ducks_Unlimited	5			3	2				
Malette	5								
Vaughan	5								
GoldenLine	5			2					
OldHazeldean	5		1	3			1		
StoneySwamp	5		2						
PowerStation	6								
Schaubs	6								
Bank	6						2		
AbandonedFarm	6								
MacHardy	6								
Galetta	6								
IvyAcres	6						2		
Carbine	6								
Lairg	6								
CercleDesErables	6			2			3		
GatineauPark	6						3		
StAmour	6								
Vaughan	6				1				
GoldenLine	6								
OldHazeldean	6						1	1	
StoneySwamp	6				1				
Bouvier	6								
Rheal	6								
Groulx	6								
Ducks_Unlimited	6				1				
Malette	6								
StrawberryFields	6								
FrenchSettlement	6			3			2		
TwoRocks	6								
Buckwheat	6								
Kennedy	6				1				
Jordon	6				1		1		

Gibson's	6					1		
Holmes	6			1				
NoAdmittance	6							
8thLine	6							
Navan	6			1				
Larose1	6		1				1	
Larose2	6						1	
Larose3	6						1	
Wilson	6							
GravelPit	6							
Bilmer	6							
8thLine	7					1		
Navan	7			1				
Larose1	7					2	2	
Larose2	7							
Larose3	7						3	
Wilson	7							
GravelPit	7							
Bilmer	7							
MacHardy	7			1		1		
Galetta	7							
IvyAcres	7					2		
Carbine	7							
Lairg	7					2		
CercleDesErables	7							
GatineauPark	7							
StAmour	7							
PowerStation	7							
Schaubs	7					1		
Bank	7							
AbandonedFarm	7							
Vaughan	7							
GoldenLine	7							
OldHazeldean	7							
StoneySwamp	7							
Bouvier	7		2	1				
Rheal	7		1					
Groulx	7						1	
Ducks_Unlimited	7							
Malette	7							
StrawberryFields	7							
FrenchSettlement	7							
TwoRocks	7							
Buckwheat	7							
Kennedy	7							
Jordon	7			1		1		
Gibson's	7							
Holmes	7							
NoAdmittance	7							
StrawberryFields	8							
FrenchSettlement	8							
TwoRocks	8							
Buckwheat	8							
Kennedy	8							
Jordon	8							

Gibson's	8								
Holmes	8								
NoAdmittance	8								
Vaughan	8								
GoldenLine	8								
OldHazeldean	8								
StoneySwamp	8								
Bouvier	8								
Rheal	8								
Groulx	8								
Ducks_Unlimited	8								
Malette	8								
Wilson	8								
GravelPit	8								
Bilmer	8								
8thLine	8								
Navan	8								
Larose1	8							1	
Larose2	8							1	
Larose3	8								
MacHardy	8								
Galetta	8								
IvyAcres	8							1	
Carbine	8								
Lairg	8								
CercleDesErables	8								
GatineauPark	8								
StAmour	8								
PowerStation	8								
Schaubs	8						1		
Bank	8								
AbandonedFarm	8								
PowerStation	D1			1					
Schaubs	D1								
Bank	D1								
AbandonedFarm	D1								
StrawberryFields	D1								
FrenchSettlement	D1								
TwoRocks	D1			2					
Buckwheat	D1								
MacHardy	D1								
Galetta	D1								
IvyAcres	D1								
Carbine	D1								
PowerStation	D2								
Schaubs	D2								
Bank	D2								
AbandonedFarm	D2								
Kennedy	D2								
Jordon	D2								
Gibson's	D2								
Holmes	D2				2				
NoAdmittance	D2								
8thLine	D2								
Navan	D2								

Larose1	D2			1					
Larose2	D2								
Larose3	D2								
Bouvier	D2								
Rheal	D2								
Groulx	D2								
Ducks_Unlimited	D2								
Malette	D2								
MacHardy	D2								
Galetta	D2					1			
IvyAcres	D2								
Carbine	D2								
Vaughan	D2								
GoldenLine	D2								
OldHazeldean	D2		3						
StoneySwamp	D2								
Lairg	D2								
CercleDesErables	D2								
GatineauPark	D2								
StAmour	D2								
StrawberryFields	D2								
FrenchSettlement	D2								
TwoRocks	D2								
Buckwheat	D2								
Wilson	D2								
GravelPit	D2								
Bilmer	D2								

2005 Field Data - Visual Day Surveys - Number of adult frogs

A * beside the survey indicates that this survey was not used in analyses due to inclement weather conditions.

Species are: Species: WDF = Wood frog, WCF = Western chorus frog; SPP = Spring peeper; NLF = Northern leopard frog; AMT = American toad; GTF = Gray treefrog; GRF = Green frog; MIF = Mink frog; BUF = Bull frog.

Pondname	Survey	WDF	WCF	SPP	AMT	NLF	GTF	GRF	BUF	MIF
PowerStation	v1									
Schaubs	v1									
Bank	v1									
AbandonedFarm	v1					1				
8thLine	v1							4		
Navan	v1					1				
Larose1	v1									
Larose2	v1							2		
Larose3	v1									
Bouvier	v1									
Rheal	v1									
Groulx	v1									
Ducks_Unlimited	v1									
Malette	v1									
Kennedy	v1									
Jordon	v1					3		16		
Gibson's	v1									
Holmes	v1									
NoAdmittance	v1					2				
MacHardy	v1									
Galetta	v1					1			1	
IvyAcres	v1							3		
Carbine	v1									
Vaughan	v1									
GoldenLine	v1							2		
OldHazeldean	v1				1			1		
StoneySwamp	v1					6		3		
Lairg	v1									
CercleDesErables	v1									
GatineauPark	v1			1				1		
StAmour	v1							1		
StrawberryFields	v1					4		2		
FrenchSettlement	v1									
TwoRocks	v1							1		
Buckwheat	v1					1				
Wilson	v1									
GravelPit	v1									
Bilmer	v1									
8thLine	v2							35		
Navan	v2				3	9		3		
Larose1	v2							1		
Larose2	v2					9		1		

Larose3	v2								
StrawberryFields	v2						1		
FrenchSettlement	v2								
TwoRocks	v2				1	2	1		
Buckwheat	v2								
PowerStation	v2				1	1			
Schaubs	v2								
Bank	v2					2			
AbandonedFarm	v2					3			
Lairg	v2						24		1
CercleDesErables	v2						6		
GatineauPark	v2	1		1			13		1
StAmour	v2	1					24		1
MacHardy	v2					11	5		
Galetta	v2				2	3	5		
IvyAcres	v2	1	1		4		8		
Carbine	v2						1		
Kennedy	v2					1			
Jordon	v2				3	2	46		
Gibson's	v2					5	4		
Holmes	v2				1	4		2	
NoAdmittance	v2					3	11		
Vaughan	v2						7		4
GoldenLine	v2					1	4		
OldHazeldean	v2						4		
StoneySwamp	v2					3	15	1	1
Wilson	v2								
GravelPit	v2								
Bilmer	v2				1		6		
Bouvier	v2						2		
Rheal	v2						3		
Groulx	v2					10	2	1	
Ducks_Unlimited	v2								
Malette	v2								
Wilson	v2*								
GravelPit	v2*								
Bilmer	v2*								
Vaughan	v2*					1	4		
GoldenLine	v2*						2		
OldHazeldean	v2*						3		
StoneySwamp	v2*						7		
Bouvier	v2*								
Rheal	v2*								
Groulx	v2*					4	1		
Ducks_Unlimited	v2*								
Malette	v2*								
PowerStation	v3						1		
Schaubs	v3						6		
Bank	v3						2		
AbandonedFarm	v3						8		
StrawberryFields	v3						6		
FrenchSettlement	v3								
TwoRocks	v3						9		
Buckwheat	v3	nothing seen in pond							

Lairg	v3							16		1
CercleDesErables	v3							39		
GatineauPark	v3							14		
StAmour	v3				1			26		3
8thLine	v3							36		
Navan	v3							21		
Larose1	v3							11		
Larose2	v3					1		4		
Larose3	v3							56		
Wilson	v3							5		
GravelPit	v3							5		
Bilmer	v3							13		
MacHardy	v3							5		
Galetta	v3							7		
IvyAcres	v3							12		
Carbine	v3							3		
Vaughan	v3							14		1
GoldenLine	v3							13		
OldHazeldean	v3	1				1		24		
StoneySwamp	v3					3		17		
Bouvier	v3							1		
Rheal	v3							20		
Groulx	v3							1		
Ducks_Unlimited	v3							1		
Malette	v3							1		
Kennedy	v3							9		
Jordon	v3							31		
Gibson's	v3					1		7		
Holmes	v3							19		
NoAdmittance	v3							3		

2005 Field Data - Visual Day Surveys - Number of juvenile frogs

NOTE: Juvenile frogs were only used in the analysis to calculate species richness (that is, species richness = all frogs seen or heard at a pond, including juveniles).

A * beside the survey indicates that this survey was not used in analyses due to inclement weather conditions.

Species are: Species: WDF = Wood frog, WCF = Western chorus frog; SPP = Spring peeper; NLF = Northern leopard frog; AMT = American toad; GTF = Gray treefrog; GRF = Green frog; MIF = Mink frog; BUF = Bull frog.

Pondname	Survey	WDF	WCF	SPP	AMT	NLF	GTF	GRF	BUF	MIF
PowerStation	v1									
Schaubs	v1									
Bank	v1									
AbandonedFarm	v1									
8thLine	v1									
Navan	v1									
Larose1	v1									
Larose2	v1									
Larose3	v1									
Bouvier	v1									
Rheal	v1									
Groulx	v1									
Ducks_Unlimited	v1									
Malette	v1									
Kennedy	v1									
Jordon	v1									
Gibson's	v1									
Holmes	v1									
NoAdmittance	v1									
MacHardy	v1									
Galetta	v1									
IvyAcres	v1									
Carbine	v1									
Vaughan	v1									
GoldenLine	v1									
OldHazeldean	v1									
StoneySwamp	v1					15		4		
Lairg	v1									
CercleDesErables	v1									
GatineauPark	v1							6		
StAmour	v1									
StrawberryFields	v1									
FrenchSettlement	v1									
TwoRocks	v1							1		
Buckwheat	v1							1		
Wilson	v1									
GravelPit	v1									
Bilmer	v1									
8thLine	v2							5		
Navan	v2									

Larose1	v2							2		
Larose2	v2									
Larose3	v2							7		
StrawberryFields	v2									
FrenchSettlement	v2									
TwoRocks	v2									
Buckwheat	v2									
PowerStation	v2									
Schaubs	v2									
Bank	v2									
AbandonedFarm	v2									
Lairg	v2							13		
CercleDesErables	v2							2		
GatineauPark	v2					1		38		
StAmour	v2							12		
MacHardy	v2					1		6		
Galetta	v2									
IvyAcres	v2							28		
Carbine	v2									
Kennedy	v2							1		
Jordon	v2					1		12		
Gibson's	v2							2		
Holmes	v2									
NoAdmittance	v2							10		
Vaughan	v2									
GoldenLine	v2					1				
OldHazeldean	v2									
StoneySwamp	v2					10		3		
Wilson	v2									
GravelPit	v2									
Bilmer	v2									
Bouvier	v2									
Rheal	v2									
Groulx	v2									
Ducks_Unlimited	v2									
Malette	v2									
Wilson	v2*									
GravelPit	v2*									
Bilmer	v2*									
Vaughan	v2*					1		1		
GoldenLine	v2*					1		3		
OldHazeldean	v2*									
StoneySwamp	v2*					3				
Bouvier	v2*									
Rheal	v2*									
Groulx	v2*									
Ducks_Unlimited	v2*									
Malette	v2*									
PowerStation	v3					10(x3)				
Schaubs	v3							1		
Bank	v3							4		
AbandonedFarm	v3					1000+		39(x2)		
StrawberryFields	v3							12		
FrenchSettlement	v3							10		
TwoRocks	v3				170+			35		

Buckwheat	v3									
GatineauPark	v3				1			282(+100)		
StAmour	v3							119		2
Lairg	v3							31		
CercleDesErables	v3							72		
MacHardy	v3							110		
Galetta	v3							23		
IvyAcres	v3							41		
Carbine	v3							9		
Vaughan	v3							5		
GoldenLine	v3							75		
OldHazeldean	v3					17		5		
StoneySwamp	v3					350+ estimate		5		
8thLine	v3							29		
Navan	v3							160		
Larose1	v3							75		
Larose2	v3									
Larose3	v3							16		
Wilson	v3									
GravelPit	v3									
Bilmer	v3							26		
Bouvier	v3				1			20		
Rheal	v3							30		
Groulx	v3							17		
Ducks_Unlimited	v3					8		13		
Malette	v3									
Kennedy	v3						1	45		
Jordon	v3							6		
Gibson's	v3							15		
Holmes	v3					6		172		
NoAdmittance	v3									

Chapter 2 Raw data collected in 2006

Environmental Data

Survey - 1 to 8 - night surveys

* indicates other surveys that were not used in the final analysis due to inclement weather during the survey.

Wind - Beaufort wind scale:

0	Calm	Calm, smoke rises vertically
1	Light Air	Smoke drift indicates wind direction, still wind vanes
2	Light Breeze	Wind felt on face, leaves rustle, vanes begin to move
3	Gentle Breeze	Leaves and small twigs constantly moving, light flags extended
4	Moderate Breeze	Dust, leaves, and loose paper lifted, small tree branches move
5	Fresh Breeze	Small trees in leaf begin to sway
6	Strong Breeze	Larger tree branches moving, whistling in wires
7	Near Gale	Whole trees moving, resistance felt walking against wind
8	Gale	Whole trees in motion, resistance felt walking against wind

Cloud

0	clear
1	partly cloudy or variable
2	cloudy or overcast
3	fog
4	drizzle
5	rain

Temp - Temperature in degrees Celsius.

Note: End time was not recorded; was always 5 minutes after start time.

Pondname	Survey	Date	StartTime	Wind	Cloud	Temp
GravelPit	1	02/04/2006	21:15	0	0	5
Bilmer	1	02/04/2006	22:18	0	0	0
Wilson	1	02/04/2006	20:35	1	1	4
Ivy Acres	1	03/04/2006	20:05	3	4	8
Carbine	1	03/04/2006	20:18	3	4	8
Vaughan	1	03/04/2006	20:50	3	2	7
GoldenLine	1	03/04/2006	21:50	3	5	7
OldHazeldean	1	03/04/2006	22:11	3	5	7
Bouvier	1	03/04/2006	20:02	0	2	10
Rheal	1	03/04/2006	20:42	4	2	9
Groulx	1	03/04/2006	21:05	4	2	9
DucksUnlimited	1	03/04/2006	21:30	5	5	6
Malette	1	03/04/2006	21:50	4	5	5
PowerStation	1	06/04/2006	20:05	0	0	5

French Settlement	1	06/04/2006	20:35	1	0	7
Jordon	1	06/04/2006	21:10	1	0	2
Gibson's	1	06/04/2006	21:25	1	1	2
Holmes	1	06/04/2006	21:40	1	1	5
8thLine	1	06/04/2006	20:06	1	0	7
Navan	1	06/04/2006	20:26	1	1	5
Larose1	1	06/04/2006	21:01	1	1	4
Larose2	1	06/04/2006	21:14	1	1	3
Larose3	1	06/04/2006	21:35	1	1	3
GravelPit	2	12/04/2006	21:10	2	2	14
Bilmer	2	12/04/2006	20:10	1	2	13
Wilson	2	12/04/2006	21:25	1	4	15
Ivy Acres	2	13/04/2006	21:58	0	0	8
Carbine	2	13/04/2006	21:35	0	1	9.5
Vaughan	2	13/04/2006	20:59	0	0	8
GoldenLine	2	13/04/2006	20:40	1	0	9
OldHazeldean	2	13/04/2006	20:15	1	0	12.5
Bouvier	2	13/04/2006	21:47	1	0	4
Rheal	2	13/04/2006	21:11	1	0	6
Groulx	2	13/04/2006	20:50	2	1	7
DucksUnlimited	2	13/04/2006	20:30	2	2	7
Malette	2	13/04/2006	20:15	3	2	8
PowerStation	2	14/04/2006	22:06	1	2	13
French Settlement	2	14/04/2006	21:41	0	2	13
Jordon	2	14/04/2006	21:06	1	0	11
Gibson's	2	14/04/2006	20:52	0	0	12
Holmes	2	14/04/2006	20:26	1	1	13
8thLine	2	14/04/2006	21:35	0	1	12
Navan	2	14/04/2006	21:18	0	0	12
Larose1	2	14/04/2006	20:50	0	1	14
Larose2	2	14/04/2006	20:33	0	2	14
Larose3	2	14/04/2006	20:15	0	2	14
GravelPit	3	18/04/2006	23:00	0	1	10
Bilmer	3	18/04/2006	21:25	0	0	11
Wilson	3	18/04/2006	22:38	1	0	11
Ivy Acres	3	20/04/2006	21:39	1	0	11
Carbine	3	20/04/2006	22:19	1	0	8
Vaughan	3	20/04/2006	20:27	0	0	15
GoldenLine	3	20/04/2006	20:46	1	0	13
OldHazeldean	3	20/04/2006	21:10	2	0	10
Bouvier	3	20/04/2006	21:50	0	0	10
Rheal	3	20/04/2006	22:35	3	0	13
Groulx	3	20/04/2006	20:29	1	0	14
DucksUnlimited	3	20/04/2006	20:52	1	0	11
Malette	3	20/04/2006	21:10	0	0	11
PowerStation	3	21/04/2006	21:40	4	0	14
French Settlement	3	21/04/2006	22:10	3	0	14
Jordon	3	21/04/2006	20:25	5	2	16
Gibson's	3	21/04/2006	20:41	5	2	15
Holmes	3	21/04/2006	20:55	5	1	15
8thLine	3	21/04/2006	21:58	3	1	12
Navan	3	21/04/2006	21:40	4	1	13
Larose1	3	21/04/2006	20:25	2	1	15
Larose2	3	21/04/2006	20:35	3	1	15
Larose3	3	21/04/2006	20:56	3	1	13

GravelPit	4*	25/04/2006	20:31	0	0	2
Bilmer	4*	25/04/2006	21:56	0	0	1
Wilson	4*	25/04/2006	22:33	0	0	2
GravelPit	4	26/04/2006	20:31	2	3	4
Bilmer	4	26/04/2006	21:36	2	4	5
Wilson	4	26/04/2006	22:23	1	1	5
PowerStation	4	27/04/2006	20:57	1	0	6
French Settlement	4	27/04/2006	20:30	1	1	5
Jordon	4	27/04/2006	22:09	1	0	3
Gibson's	4	27/04/2006	21:54	1	0	4
Holmes	4	27/04/2006	21:36	1	0	3
8thLine	4	27/04/2006	20:45	0	0	4.5
Navan	4	27/04/2006	20:25	1	0	4
Larose1	4	27/04/2006	21:59	0	0	2
Larose2	4	27/04/2006	21:44	0	0	2.5
Larose3	4	27/04/2006	21:25	0	0	2.5
Ivy Acres	4	28/04/2006	21:15	0	0	6
Carbine	4	28/04/2006	20:51	0	0	5
Vaughan	4	28/04/2006	22:15	1	0	4
GoldenLine	4	28/04/2006	20:20	0	0	4
OldHazeldean	4	28/04/2006	21:56	0	0	7
Bouvier	4	28/04/2006	21:08	0	0	3.5
Rheal	4	28/04/2006	20:30	0	0	6.5
Groulx	4	28/04/2006	22:40	0	0	1.5
DucksUnlimited	4	28/04/2006	22:15	0	0	1
Malette	4	28/04/2006	22:01	0	0	0.5
Wilson	5	08/05/2006	21:28	1	0	12
GravelPit	5	09/05/2006	22:31	1	0	12
Bilmer	5	09/05/2006	23:34	0	1	11
PowerStation	5	10/05/2006	20:47	0	0	17
French Settlement	5	10/05/2006	21:16	4	1	18
Jordon	5	10/05/2006	21:50	3	0	16
Gibson's	5	10/05/2006	22:06	4	0	16
Holmes	5	10/05/2006	22:23	3	0	16
8thLine	5	10/05/2006	20:46	0	0	17
Navan	5	10/05/2006	21:03	2	1	18
Larose1	5	10/05/2006	21:32	3	1	18
Larose2	5	10/05/2006	21:43	3	1	16
Larose3	5	10/05/2006	22:03	4	0	16
Ivy Acres	5	11/05/2006	20:50	2	1	18
Carbine	5	11/05/2006	21:13	3	1	18
Vaughan	5	11/05/2006	21:50	1	1	18
GoldenLine	5	11/05/2006	22:13	3	1	18
OldHazeldean	5	11/05/2006	22:37	4	2	18
Bouvier	5	11/05/2006	20:46	4	2	23
Rheal	5	11/05/2006	21:30	4	2	18
Groulx	5	11/05/2006	21:54	4	2	18
DucksUnlimited	5	11/05/2006	22:21	7	2	18
Malette	5	11/05/2006	22:41	7	2	18
GravelPit	6	24/05/2006	22:03	1	0	14
Bilmer	6	24/05/2006	21:02	0	0	14
Wilson	6	24/05/2006	22:13	5	2	15
Ivy Acres	6	26/05/2006	22:48	0	0	17
Carbine	6	26/05/2006	22:24	0	0	16
Vaughan	6	26/05/2006	21:50	0	1	17

GoldenLine	6	26/05/2006	21:32	0	2	17
OldHazeldean	6	26/05/2006	21:04	0	2	18
Bouvier	6	26/05/2006	23:00	0	1	18
Rheal	6	26/05/2006	22:17	0	1	18
Groulx	6	26/05/2006	21:53	0	1	17
DucksUnlimited	6	26/05/2006	21:25	0	2	18
Malette	6	26/05/2006	21:03	0	2	18
PowerStation	6	28/05/2006	22:40	0	3	20
French Settlement	6	28/05/2006	22:10	0	3	21
Jordon	6	28/05/2006	21:34	1	3	22
Gibson's	6	28/05/2006	21:16	1	2	24
Holmes	6	28/05/2006	21:00	0	2	24
8thLine	6	28/05/2006	22:30	0	2	20
Navan	6	28/05/2006	22:10	0	2	20
Larose1	6	28/05/2006	21:42	0	3	20
Larose2	6	28/05/2006	21:27	0	2	20
Larose3	6	28/05/2006	21:06	0	2	20
GravelPit	7	18/06/2006	23:58	1	0	20
Bilmer	7	18/06/2006	22:30	1	0	25
Wilson	7	18/06/2006	21:27	4	1	26
PowerStation	7	20/06/2006	23:15	1	0	14
French Settlement	7	20/06/2006	23:58	0	0	13
Jordon	7	20/06/2006	21:26	1	0	19
Gibson's	7	20/06/2006	21:49	1	0	18
Holmes	7	20/06/2006	22:15	1	0	15
8thLine	7	20/06/2006	22:43	0	0	15
Navan	7	20/06/2006	23:00	0	0	15
Larose1	7	20/06/2006	21:28	0	0	17
Larose2	7	20/06/2006	21:40	0	0	17
Larose3	7	20/06/2006	22:00	0	0	17
Ivy Acres	7	21/06/2006	23:11	0	2	19
Carbine	7	21/06/2006	23:55	2	2	19
Vaughan	7	21/06/2006	21:26	0	0	18
GoldenLine	7	21/06/2006	21:48	2	1	19
OldHazeldean	7	21/06/2006	22:38	1	2	19
Bouvier	7	21/06/2006	23:00	0	0	19
Rheal	7	21/06/2006	23:38	0	0	19
Groulx	7	21/06/2006	21:31	1	0	18
DucksUnlimited	7	21/06/2006	22:00	0	0	19
Malette	7	21/06/2006	NO SURVEY DONE			
GravelPit	8	12/07/2006	21:15	2	2	20
Bilmer	8	12/07/2006	22:43	0	0	22
Wilson	8	12/07/2006	23:20	2	1	19
PowerStation	8	14/07/2006	21:43	1	0	24
French Settlement	8	14/07/2006	21:15	1	2	23
Jordon	8	14/07/2006	23:18	1	1	22
Gibson's	8	14/07/2006	23:00	1	1	23
Holmes	8	14/07/2006	22:42	1	1	23
8thLine	8	14/07/2006	21:36	1	1	24
Navan	8	14/07/2006	21:19	1	1	23
Larose1	8	14/07/2006	22:55	0	0	23
Larose2	8	14/07/2006	22:42	0	0	23
Larose3	8	14/07/2006	22:22	0	0	25
Ivy Acres	8	15/07/2006	21:47	1	1	23
Carbine	8	15/07/2006	21:15	1	1	23

Vaughan	8	15/07/2006	23:09	0	0	23
GoldenLine	8	15/07/2006	22:58	0	0	23
OldHazeldean	8	15/07/2006	22:19	1	0	23
Bouvier	8	15/07/2006	21:55	0	0	25
Rheal	8	15/07/2006	21:18	0	2	26
Groulx	8	15/07/2006	22:37	0	0	22
DucksUnlimited	8	15/07/2006	22:08	0	0	22
Malette	8	15/07/2006	22:45	0	0	22

2006 Field Data - Call Surveys - Calling directly at pond

Species are: Species: WDF = Wood frog, WCF = Western chorus frog; SPP = Spring peeper; NLF = Northern leopard frog; AMT = American toad; GTF = Gray treefrog; GRF = Green frog; MIF = Mink frog; BUF = Bull frog.

Calling activity for each species

- 0** no individuals calling
- 1** individual(s) can be counted, calls are not overlapping
- 2** calls of <15 individuals can be distinguished, but there is some overlapping
- 3** calls of ≥ 15 individuals

Pondname	Survey	WDF	WCF	SPP	AMT	NLF	GTF	GRF	BUF
GravelPit	1								
Bilmer	1								
Wilson	1								
Ivy Acres	1								
Carbine	1								
Vaughan	1								
GoldenLine	1								
OldHazeldean	1								
Bouvier	1								
Rheal	1								
Groulx	1								
DucksUnlimited	1								
Malette	1								
PowerStation	1								
French Settlement	1								
Jordon	1								
Gibson's	1								
Holmes	1								
8thLine	1								
Navan	1								
Larose1	1								
Larose2	1								
Larose3	1								
GravelPit	2								
Bilmer	2	2		3					
Wilson	2								
Ivy Acres	2	1							
Carbine	2			1					
Vaughan	2								
GoldenLine	2	1		2					
OldHazeldean	2								
Bouvier	2			1					
Rheal	2	2		3					
Groulx	2								
DucksUnlimited	2								
Malette	2			1					
PowerStation	2								
French Settlement	2	3		3					
Jordon	2					1		1	
Gibson's	2								

Holmes	2	1		3		1			
8thLine	2			1					
Navan	2								
Larose1	2								
Larose2	2								
Larose3	2			2					
GravelPit	3			1					
Bilmer	3			3		1			
Wilson	3								
Ivy Acres	3					1			
Carbine	3			2		1			
Vaughan	3			2					
GoldenLine	3			3	1	1			
OldHazeldean	3				2				
Bouvier	3			2	1				
Rheal	3	1		3					
Groulx	3								
DucksUnlimited	3								
Malette	3			3		1			
PowerStation	3	1				1			
French Settlement	3			2					
Jordon	3				2	1			
Gibson's	3								
Holmes	3			3					
8thLine	3			1					
Navan	3			2		1			
Larose1	3								
Larose2	3								
Larose3	3			2					
GravelPit	4*			1					
Bilmer	4*			3					
Wilson	4*								
GravelPit	4			2					
Bilmer	4			2		1			
Wilson	4								
PowerStation	4	1				1			
French Settlement	4			2					
Jordon	4					1			
Gibson's	4			1					
Holmes	4			2		1			
8thLine	4			1					
Navan	4			2		1			
Larose1	4								
Larose2	4								
Larose3	4								
Ivy Acres	4								
Carbine	4			2		1			
Vaughan	4			3					
GoldenLine	4			2					
OldHazeldean	4		1	3					
Bouvier	4			2					
Rheal	4			3					
Groulx	4					2			
DucksUnlimited	4					2			
Malette	4			3		1			

Wilson	5				2				
GravelPit	5			1	1				
Bilmer	5			1					
PowerStation	5				1				
French Settlement	5			3			1		
Jordon	5				2			1	
Gibson's	5			1	1				
Holmes	5			2	1	1	1		
8thLine	5			3					
Navan	5			3	1	1			
Larose1	5								
Larose2	5								
Larose3	5			1					
Ivy Acres	5				1				
Carbine	5			2					
Vaughan	5			3		1			
GoldenLine	5			2			2		
OldHazeldean	5								
Bouvier	5			3	1	1			
Rheal	5			3					
Groulx	5			2	1	1			
DucksUnlimited	5			2					
Malette	5			2	2				
GravelPit	6			1					
Bilmer	6			1			3		
Wilson	6								
Ivy Acres	6								
Carbine	6				2		1		1
Vaughan	6			3				1	
GoldenLine	6			1			3	1	
OldHazeldean	6								
Bouvier	6							1	
Rheal	6			2			2	1	
Groulx	6			1	1			1	
DucksUnlimited	6			2	1				
Malette	6			2	1	1			
PowerStation	6				1				
French Settlement	6						3	1	
Jordon	6							2	
Gibson's	6				1				
Holmes	6			1			3	1	
8thLine	6								
Navan	6			1		1	2	1	
Larose1	6								
Larose2	6								
Larose3	6							1	
GravelPit	7						1	1	
Bilmer	7						2	1	
Wilson	7							1	
PowerStation	7							1	
French Settlement	7							1	
Jordon	7				1			1	
Gibson's	7				1			1	
Holmes	7						2	2	
8thLine	7							1	

Navan	7							2	
Larose1	7							1	1
Larose2	7								
Larose3	7							1	
Ivy Acres	7							1	
Carbine	7								
Vaughan	7							1	
GoldenLine	7						2	1	
OldHazeldean	7							1	
Bouvier	7							1	
Rheal	7							1	
Groulx	7							2	
DucksUnlimited	7							1	
Malette	7								
GravelPit	8							1	
Bilmer	8							1	
Wilson	8							1	
PowerStation	8							1	
French Settlement	8							1	
Jordon	8							2	
Gibson's	8							2	
Holmes	8							2	
8thLine	8								
Navan	8							1	
Larose1	8								1
Larose2	8								
Larose3	8							1	
Ivy Acres	8							1	
Carbine	8								
Vaughan	8							1	
GoldenLine	8							2	
OldHazeldean	8							1	
Bouvier	8							1	
Rheal	8							1	
Groulx	8							2	1
DucksUnlimited	8							2	
Malette	8							1	

2006 Field Data - Call Surveys - Calling within 100 m of pond edge

Species are: Species: WDF = Wood frog, WCF = Western chorus frog; SPP = Spring peeper; NLF = Northern leopard frog; AMT = American toad; GTF = Gray treefrog; GRF = Green frog; MIF = Mink frog; BUF = Bull frog.

Calling activity for each species

- 0** no individuals calling
- 1** individual(s) can be counted, calls are not overlapping
- 2** calls of <15 individuals can be distinguished, but there is some overlapping
- 3** calls of ≥ 15 individuals

Pondname	Survey	WDF	WCF	SPP	AMT	NLF	GTF	GRF	BUF
GravelPit	1								
Bilmer	1								
Wilson	1								
Ivy Acres	1								
Carbine	1								
Vaughan	1								
GoldenLine	1								
OldHazeldean	1								
Bouvier	1								
Rheal	1								
Groulx	1								
DucksUnlimited	1								
Malette	1								
PowerStation	1								
French Settlement	1								
Jordon	1								
Gibson's	1								
Holmes	1								
8thLine	1								
Navan	1								
Larose1	1								
Larose2	1	1		1					
Larose3	1								
GravelPit	2								
Bilmer	2								
Wilson	2								
Ivy Acres	2								
Carbine	2								
Vaughan	2								
GoldenLine	2								
OldHazeldean	2		2						
Bouvier	2	2		2					
Rheal	2								
Groulx	2								
DucksUnlimited	2								
Malette	2								
PowerStation	2	1							
French Settlement	2	3							
Jordon	2								

Gibson's	2								
Holmes	2								
8thLine	2								
Navan	2			1					
Larose1	2	1		3		1			
Larose2	2	1		2		1			
Larose3	2	3		3					
GravelPit	3								
Bilmer	3				1				
Wilson	3			1					
Ivy Acres	3					1			
Carbine	3								
Vaughan	3			3					
GoldenLine	3								
OldHazeldean	3		1	3					
Bouvier	3								
Rheal	3								
Groulx	3			1					
DucksUnlimited	3			3	2	3			
Malette	3								
PowerStation	3			1	1				
French Settlement	3			2					
Jordon	3								
Gibson's	3								
Holmes	3				1				
8thLine	3								
Navan	3								
Larose1	3			3		1			
Larose2	3			2					
Larose3	3				1	1			
GravelPit	4*			1					
Bilmer	4*								
Wilson	4*								
GravelPit	4								
Bilmer	4			3					
Wilson	4								
PowerStation	4			1					
French Settlement	4			3					
Jordon	4								
Gibson's	4								
Holmes	4								
8thLine	4								
Navan	4								
Larose1	4					1			
Larose2	4			2					
Larose3	4	1		3					
Ivy Acres	4								
Carbine	4								
Vaughan	4								
GoldenLine	4								
OldHazeldean	4								
Bouvier	4								
Rheal	4								
Groulx	4			1					
DucksUnlimited	4					1			

Malette	4								
Wilson	5								
GravelPit	5								
Bilmer	5			1	2				
PowerStation	5			2					
French Settlement	5								
Jordon	5								
Gibson's	5								
Holmes	5								
8thLine	5								
Navan	5								
Larose1	5			2	1				
Larose2	5			1					
Larose3	5			3	2				
Ivy Acres	5								
Carbine	5								
Vaughan	5								
GoldenLine	5				1				
OldHazeldean	5			1					
Bouvier	5								
Rheal	5			3					
Groulx	5								
DucksUnlimited	5				1				
Malette	5								
GravelPit	6								
Bilmer	6								
Wilson	6								
Ivy Acres	6						1		
Carbine	6								
Vaughan	6								
GoldenLine	6								
OldHazeldean	6						3	1	
Bouvier	6				1				
Rheal	6								
Groulx	6						1		
DucksUnlimited	6								
Malette	6								
PowerStation	6								
French Settlement	6								
Jordon	6				1		1		
Gibson's	6								
Holmes	6								
8thLine	6								
Navan	6								
Larose1	6				1			1	
Larose2	6						1		
Larose3	6			2	1		1	1	
GravelPit	7								
Bilmer	7								
Wilson	7								
PowerStation	7								
French Settlement	7								
Jordon	7				1		1		
Gibson's	7								
Holmes	7								

8thLine	7								
Navan	7								
Larose1	7						1	1	
Larose2	7						1		
Larose3	7			1					
Ivy Acres	7								1
Carbine	7					1	1		
Vaughan	7								
GoldenLine	7					2			
OldHazeldean	7					1	2		
Bouvier	7								
Rheal	7								
Groulx	7								
DucksUnlimited	7								
Malette	7								
GravelPit	8								
Bilmer	8								
Wilson	8								
PowerStation	8								
French Settlement	8								
Jordon	8						1		
Gibson's	8								
Holmes	8					1			
8thLine	8								
Navan	8								
Larose1	8						2		
Larose2	8								
Larose3	8								
Ivy Acres	8						1		
Carbine	8								
Vaughan	8								
GoldenLine	8								
OldHazeldean	8						1		
Bouvier	8								
Rheal	8								
Groulx	8								
DucksUnlimited	8								
Malette	8								

Appendix 3: Raw field data for Chapter 3 and 4 (2006 and 2007 data)

Electronic versions of this data and the summarized version of this data used in the analyses are available electronically on the attached CD and is available upon request from the Carleton University Library. The files 'RawData2006.xls' and 'RawData2007.xls' contain all information in Appendix 3 except site and pond information. The also contain additional data on tadpole and juvenile frogs, as well as field notes. None of this additional information was used in any part of this thesis as I judged it not to be 100% reliable. 'Chapter3_4DataSummary.xls' contain the summary files used for analysis, site and pond information, and the amount of forest, wetland and traffic in the landscape at the 100 to 2000 m scale.

Chapter 3 & 4 Pond information: IMPORTANT: The X and Y coordinates are NOT a guarantee of access to any site, but especially not to sites on private land. DO NOT attempt to access any sites on private land without first contacting the landowners. Please also contact me (felix.eigenbrod@gmail.com) BEFORE re-surveying the sites if you are interested in doing so; I may be able to provide additional information on who owns the land on which the sites are located which I cannot make public due to confidentiality agreements.

Site coordinates are in UTM (Zone 18N); the datum is NAD83.

Chapter - Indicates if sites were used the analyses for Chapter 3 (3), Chapter 4 (4), or both (3,4); none indicates that the data was used in neither analysis. Note that 3 ponds (Bilmer, Gravel Pit and Wilson) were also surveyed in 2005 and used in the analyses for Chapter 2.

pH and conductivity are averages from 4 points on the edge of each pond located a maximum distance apart and were collected in 2006. Pond perimeter was measured in 2006 using a Trimble GPS. More information is available in the methods of Chapter 2, 3 and 4.

Pond Name	Chapter	X Coordinate	Y Coordinate	pH	Conductivity	Pond Perimeter (m)	Private?
Barkley	4	NA	NA	7.74	734.25	110.747	y
Beauregard	3,4	493077.61	4979488.088	8.4725	526.5	715.2192	y
Bilmer	3,4	509822.65	4989708.65	8.18	436.25	231.8748	y
Brouseville	3,4	466378.51	4963671.786	7.5775	809.25	36.61195	y
Burles	3,4	505768.93	4988928.168	8.185	353	155.1039	y
Corner	3,4	466076.17	4960549.584	7.9475	1138.25	87.6931	y
Dafoe	3,4	494960.65	4981865.43	8.14	400.5	280.7028	y
English	4	4967608.77	473481.45	8.2225	710.5	701.6405	n
Ferguson 1	none	492012.96	4978340.27	8.4875	1766.75	392.8255	y
Ferguson 2	3,4	492414.69	4978524.39	8.6325	253.5	410.8425	y
Gervais	4	4974898.33	484324.49	8.2025	449.5	118.7337	y
Godwin	3,4	461436.95	4960624.58	7.725	758.75	55.80047	y
Gravel Pit	3,4	502433.79	4986023.20	8.3825	490.5	160.8797	y

Hasson	3,4	472652.46	4967075.02	7.995	350.25	110.7437	y
Hooker	3,4	508112.56	4988665.29	8.3975	663.25	158.508	y
Luther	3,4	468543.90	4965848.03	7.7325	274.25	380.3253	y
McIntosh	3,4	493251.19	4981588.91	7.61	615.75	329.8167	y
McKenzie	3,4	490627.71	4977705.90	8.3025	980.75	724.9281	y
Pamkoski	4	4989147.29	507549.83	8.265	405	119.4261	y
Popoff	3,4	502624.98	4987957.72	8.4375	486.25	116.4032	y
Robertson	3,4	484683.14	4974030.00	7.77	675	309.9641	n
Rooney	3,4	462488.04	4956316.37	8.085	800.5	1284.144	n
Rost	3,4	469064.63	4964551.73	8.2325	343.25	83.16704	y
Sayean	3,4	463326.17	4962193.45	7.375	280.75	325.2275	y
Smith	3,4	464863.38	4961934.49	8.525	656.5	141.8106	y
Sneath	3,4	488162.55	4977873.84	8.2925	311.25	208.5344	y
Trailer	3,4	480915.43	4971864.73	8.0225	375	689.1216	y
Upper Canada	4	4978052.89	491235.97	8.3475	442.5	445.3715	y
Veltkamp	3,4	475012.54	4968703.10	7.735	490.25	308.8768	y
Venema	3,4	NA	NA	9.85	205	109.8708	y
Vol	3,4	496139.11	4982469.54	8.1325	562.25	124.3862	y
Wageman 1	3,4	487095.49	4975659.05	8.395	871.75	672.84	y
Wageman 2	none	487466.14	4975737.19	8.3625	466.25	513.9046	y
Wilson	3,4	478587.01	4970714.67	8.445	489	364.067	y
Wyands	4	4961361.48	466569.43	8.12	838.5	257.7529	y
Zeron	4	4970203.92	477691.50	9.1975	266.25	301.0192	y

Chapter 2 Pond Information (continued). See Methods of Chapter 2,3 and 4 for more information. All data was collected in 2006.

PondName	Number Of Transects	Distance Between Transects (m as measured by paces)	Average Emergent Vegetation	Average Floating Vegetation	Average Insolation	Proportion of shading of first 2 m of pond edge.	Pond Area (m ²)
Barkley	7	19	0.357143	16.07143	0.214286	0.571429	313.39
Beauregard	11	76	1.590909	1.590909	0.772727	0.181818	22216.37
Bilmer	7	38	18.57143	6.428571	0.714286	0	874.24
Brouseville	4	10	3.125	100	1	0	89.05
Burles	5	38	5	4.5	0.9	0.2	996.13
Corner	5	19	31.5	7.5	1	0	440.45
Dafoe	6	57	18.33333	5	0.666667	0.5	3599.68
English	10	76	13.75	10.25	0.7	0	20116.16
Ferguson 1	8	57	7.8125	2.8125	1	0	9975.02
Ferguson 2	9	57	5.277778	1.666667	0.722222	0.444444	7794.76
Gervais	6	19	22.08333	5.833333	0.75	0.5	926.54
Godwin	6	10	16.25	34.16667	0.666667	0.5	160.90
Gravel Pit	5	38	13	16	0.55	0.8	1018.53
Hasson	6	38	5.416667	0.833333	0.375	1	893.58
Hooker	4	38	1.25	23.75	0.75	0	429.71
Luther	8	57	29.0625	5.3125	0.34375	0.8125	4688.35
McIntosh	7	57	5.357143	3.214286	0.571429	0.857143	2427.10
McKenzie	11	76	12.27273	6.363636	0.681818	0.636364	22305.26
Pamkoski	4	38	15.625	8.75	1	0	707.39
Popoff	4	38	5.625	35	1	0	816.45
Robertson	6	57	45	12.0833	0.791667	0.333333	3429.80
Rooney	20	76	20.8	12.875	0.8625	0.1	29621.51
Rost	5	19	9	18	0.9	0.2	437.56
Sayean	8	38	44.6875	5.3125	0.625	0.625	3381.26
Smith	7	19	21.42857	24.28571	1	0	821.37
Sneath	6	38	16.66667	18.75	0.583333	0.666667	2593.04
Trailer	10	76	16	12.5	0.6	0.5	13837.48
Upper Canada	8	76	5.3125	1.25	0.5625	0.5	10761.99
Veltkamp	8	38	1.25	3.75	0.3125	0.5	1612.73
Venema	6	19	14.16667	39.58333	1	0	778.32
Vol	4	38	6.875	10.625	0.875	0.25	873.97
Wageman 1	10	76	6.5	15.5	0.5	0.6	11662.19
Wageman 2	8	76	17.5	10.9375	0.625	0.625	13509.74
Wilson	6	76	1.25	2.5	0.416667	0.833333	7389.96
Wyands	5	57	1.5	31	1	0	2721.81
Zeron	6	57	2.583333	8.75	1	0	6195.32

Chapter 3 & 4 Raw data collected in 2006

NOTE: The data is arranged in several tables. 'Site' and 'Survey' are present in each table to allow the tables to be linked if required. Data are sorted first by survey, then by survey date, then by site name.

Environmental Data - 2006

Survey - 1 to 8 - night surveys

v1 to v4 - visual day survey

v5leopardfrogs - a separate visual survey to look for young of the year leopard frogs. This was not used in the analysis except for a 'presence' of this species.

The methodology for v5 was to carefully survey the pond edges (especially promising areas such as wet grassland) for young-of year leopard frogs.

4-redone Not used in the analysis (redone) due to cold weather

Wind - Beaufort wind scale:

0	Calm	Calm, smoke rises vertically
1	Light Air	Smoke drift indicates wind direction, still wind vanes
2	Light Breeze	Wind felt on face, leaves rustle, vanes begin to move
3	Gentle Breeze	Leaves and small twigs constantly moving, light flags extended
4	Moderate Breeze	Dust, leaves, and loose paper lifted, small tree branches move
5	Fresh Breeze	Small trees in leaf begin to sway
6	Strong Breeze	Larger tree branches moving, whistling in wires
7	Near Gale	Whole trees moving, resistance felt walking against wind
8	Gale	Whole trees in motion, resistance felt walking against wind

Cloud

0	clear
1	partly cloudy or variable
2	cloudy or overcast
3	fog
4	drizzle
5	rain

Temp - Temperature in degrees Celsius.

Pondname	Survey	Date	StartTime	Wind	Cloud	Temp
Beauregard	1	01/04/2006	21:34	3	2	6
Brouseville	1	01/04/2006	20:40	5	2	5
Corner	1	01/04/2006	20:14	4	2	6
Fergusen_1	1	01/04/2006	21:03	3	2	6
Fergusen_2	1	01/04/2006	21:19	3	2	6
Godwin	1	01/04/2006	19:24	4	2	6
Luther	1	01/04/2006	20:50	5	2	5
McKenzie	1	01/04/2006	20:19	3	2	6

Rooney	1	01/04/2006	19:00	2	2	6
Rost	1	01/04/2006	21:25	5	2	5
Sayean	1	01/04/2006	19:45	4	2	6
Smith	1	01/04/2006	20:02	2	2	6
Sneath	1	01/04/2006	19:59	3	2	7
UpperCanada	1	01/04/2006	20:41	3	2	7
Wagemans_1	1	01/04/2006	19:16	3	2	6
Wagemans_2	1	01/04/2006	19:40	4	2	6
Wyands	1	01/04/2006	20:25	4	2	6
Barkley	1	02/04/2006	21:23	1	0	2
Bilmer	1	02/04/2006	22:18	0	0	0
Burles	1	02/04/2006	21:42	0	0	3.6
Dafoe	1	02/04/2006	20:40	0	0	5
English	1	02/04/2006	20:05	1	1	5
Gervais	1	02/04/2006	21:38	1	0	2
GravelPit	1	02/04/2006	21:15	0	0	5
Hasson	1	02/04/2006	19:55	1	1	5
Hooker	1	02/04/2006	22:05	0	0	1
McIntosh	1	02/04/2006	20:23	0	0	5
Pamkoski	1	02/04/2006	21:54	0	0	3.8
Popoff	1	02/04/2006	21:30?	0	0	4
Robertson	1	02/04/2006	21:15	1	0	2
Trailer	1	02/04/2006	20:50	1	1	4
Veltkamp	1	02/04/2006	20:17	1	1	4
Venema	1	02/04/2006	21:03	1	1	4
Vol	1	02/04/2006	20:58	0	0	6
Wilson	1	02/04/2006	20:35	1	1	4
Zeron	1	02/04/2006	20:27	1	1	5
Beauregard	2	11/04/2006	20:20	1	1	9
Brouseville	2	11/04/2006	21:10	1	0	8
Corner	2	11/04/2006	21:35	1	0	8
Ferguson_1	2	11/04/2006	21:00	2	1	13
Ferguson_2	2	11/04/2006	20:45	1	1	11
Godwin	2	11/04/2006	22:23	1	0	5
Luther	2	11/04/2006	20:48	1	1	9
McKenzie	2	11/04/2006	21:35	2	0	12
Rooney	2	11/04/2006	22:44	1	0	6
Rost	2	11/04/2006	20:30	1	1	9
Sayean	2	11/04/2006	22:06	1	0	6
Smith	2	11/04/2006	21:48	1	0	8
Sneath	2	11/04/2006	21:50	0	0	12
UpperCanada	2	11/04/2006	21:15	1	0	10
Wagemans_1	2	11/04/2006	22:20	1	0	11
Wagemans_2	2	11/04/2006	22:10	1	0	10
Wyands	2	11/04/2006	21:24	1	0	8
Barkley	2	12/04/2006	20:27	1	2	12
Bilmer	2	12/04/2006	20:10	1	2	13
Burles	2	12/04/2006	20:44	1	2	13
Dafoe	2	12/04/2006	21:45	2	4	14
English	2	12/04/2006	22:05	1	2	15
Gervais	2	12/04/2006	20:10	1	2	14
GravelPit	2	12/04/2006	21:10	2	2	14
Hasson	2	12/04/2006	22:15	0	2	16
Hooker	2	12/04/2006	20:21	1	2	13
McIntosh	2	12/04/2006	22:04	1	2	13

Pamkoski	2	12/04/2006	20:33	1	2	13
Popoff	2	12/04/2006	20:58	1	2	14
Robertson	2	12/04/2006	20:40	0	2	14
Trailer	2	12/04/2006	21:12	0	2	15
Veltkamp	2	12/04/2006	21:52	2	4	16
Venema	2	12/04/2006	20:55	0	2	14
Vol	2	12/04/2006	21:28	2	4	14
Wilson	2	12/04/2006	21:25	1	4	15
Zeron	2	12/04/2006	21:37	2	2	16
Barkley	3	18/04/2006	21:11	1	1	14
Bilmer	3	18/04/2006	21:25	0	0	11
Burles	3	18/04/2006	20:40	0	1	14
Dafoe	3	18/04/2006	22:20	0	0	8
English	3	18/04/2006	22:00	1	0	14
Gervais	3	18/04/2006	21:27	1	1	15
GravelPit	3	18/04/2006	23:00	0	1	10
Hasson	3	18/04/2006	21:47	1	0	14
Hooker	3	18/04/2006	21:10	0	0	11
McIntosh	3	18/04/2006	22:01	0	0	14
Pamkoski	3	18/04/2006	20:56	0	0	12
Popoff	3	18/04/2006	20:20	0	1	12
Robertson	3	18/04/2006	20:59	1	1	15
Trailer	3	18/04/2006	20:28	1	1	15
Veltkamp	3	18/04/2006	22:16	1	0	13
Venema	3	18/04/2006	20:43	1	1	15
Vol	3	18/04/2006	22:35	0	0	8
Wilson	3	18/04/2006	22:38	1	0	11
Zeron	3	18/04/2006	22:28	1	0	12
Beauregard	3	19/04/2006	21:06	1	0	16
Brouseville	3	19/04/2006	20:50	0	0	13
Corner	3	19/04/2006	20:22	0	0	12
Ferguson_1	3	19/04/2006	20:43	1	0	16
Ferguson_2	3	19/04/2006	20:55	1	0	16
Godwin	3	19/04/2006	22:10	0	0	10
Luther	3	19/04/2006	21:10	0	0	11
McKenzie	3	19/04/2006	22:15	1	0	12
Rooney	3	19/04/2006	21:50	0	0	9
Rost	3	19/04/2006	21:20	0	0	8
Sayean	3	19/04/2006	22:30	2	0	13.8
Smith	3	19/04/2006	22:50	1	0	13
Sneath	3	19/04/2006	22:01	1	0	12
UpperCanada	3	19/04/2006	20:25	1	0	19
Wagemans_1	3	19/04/2006	21:27	1	0	14
Wagemans_2	3	19/04/2006	21:49	1	0	13
Wyands	3	19/04/2006	20:37	0	0	12
Beauregard	4	24/04/2006	21:55	1	0	7
Brouseville	4	24/04/2006	22:04	2	2	7
Corner	4	24/04/2006	22:28	1	1	8
Ferguson_1	4	24/04/2006	22:25	2	0	7
Ferguson_2	4	24/04/2006	20:12	2	0	7
Godwin	4	24/04/2006	21:02	0	1	7
Luther	4	24/04/2006	21:50	0	2	7
McKenzie	4	24/04/2006	20:35	0	1	7
Rooney	4	24/04/2006	21:18	0	2	7
Rost	4	24/04/2006	21:39	0	2	7

Sayean	4	24/04/2006	20:47	0	1	7
Smith	4	24/04/2006	20:31	0	1	8
Sneath	4	24/04/2006	20:58	0	2	7
UpperCanada	4	24/04/2006	22:40	0	0	7
Wagemans_1	4	24/04/2006	21:31	0	0	7
Wagemans_2	4	24/04/2006	21:15	0	0	7
Wyands	4	24/04/2006	22:19	1	1	8
Barkley	4	26/04/2006	21:30	2	3	5
Bilmer	4	26/04/2006	21:36	2	4	5
Burles	4	26/04/2006	22:07	1	2	5
Dafoe	4	26/04/2006	20:59	2	3	6
English	4	26/04/2006	20:48	3	2	6
Gervais	4	26/04/2006	21:18	1	4	6
GravelPit	4	26/04/2006	20:31	2	3	4
Hasson	4	26/04/2006	20:58	2	2	5
Hooker	4	26/04/2006	21:48	1	2	5
McIntosh	4	26/04/2006	21:11	3	4	5
Pamkoski	4	26/04/2006	21:56	1	3	5
Popoff	4	26/04/2006	22:20	1	0	4
Robertson	4	26/04/2006	21:40	4	5	4
Trailer	4	26/04/2006	22:07	1	1	5
Veltkamp	4	26/04/2006	20:38	2	4	6
Venema	4	26/04/2006	21:51	1	1	4.5
Vol	4	26/04/2006	20:47	2	3	5
Wilson	4	26/04/2006	22:23	1	1	5
Zeron	4	26/05/2006	20:27	5	4	7
Barkley	5	08/05/2006	22:19	0	0	10
Beauregard	5	08/05/2006	22:20	1	0	10
English	5	08/05/2006	20:56	0	0	14
Ferguson_1	5	08/05/2006	22:00	0	0	10
Ferguson_2	5	08/05/2006	22:10	1	0	9
Gervais	5	08/05/2006	22:32	0	0	12
Hasson	5	08/05/2006	20:42	0	0	14
McKenzie	5	08/05/2006	21:30	0	0	12
Robertson	5	08/05/2006	22:10	0	0	9
Sneath	5	08/05/2006	21:17	0	0	14
Trailer	5	08/05/2006	21:44	1	0	13
UpperCanada	5	08/05/2006	21:45	0	0	13
Veltkamp	5	08/05/2006	21:07	0	0	14
Venema	5	08/05/2006	21:59	0	0	10
Wagemans_1	5	08/05/2006	20:55	0	0	14
Wagemans_2	5	08/05/2006	21:05	0	0	14
Wilson	5	08/05/2006	21:28	1	0	12
Zeron	5	08/05/2006	21:19	0	0	14
Bilmer	5	09/05/2006	23:34	0	1	11
Brouseville	5	09/05/2006	22:04	1	1	10
Burles	5	09/05/2006	22:57	0	1	12
Corner	5	09/05/2006	21:42	1	1	14
Dafoe	5	09/05/2006	21:23	0	0	15
Godwin	5	09/05/2006	21:05	1	1	15
GravelPit	5	09/05/2006	22:31	1	0	12
Hooker	5	09/05/2006	23:22	0	0	11
Luther	5	09/05/2006	22:17	1	2	12
McIntosh	5	09/05/2006	20:56	0	1	17
Pamkoski	5	09/05/2006	23:17	0	1	10

Popoff	5	09/05/2006	23:59	0	0	12
Rooney	5	09/05/2006	20:46	1	1	18
Rost	5	09/05/2006	22:28	1	2	10
Sayean	5	09/05/2006	21:18	1	1	12
Smith	5	09/05/2006	21:30	0	1	16
Vol	5	09/05/2006	21:45	0	0	13
Wyands	5	09/05/2006	21:51	1	2	13
Barkley	6	24/05/2006	21:19	1	1	14
Bilmer	6	24/05/2006	21:02	0	0	14
Burles	6	24/05/2006	21:37	1	0	14
Dafoe	6	24/05/2006	22:37	2	0	15
English	6	24/05/2006	22:40	3	1	15
Gervais	6	24/05/2006	21:04	0	0	14
GravelPit	6	24/05/2006	22:03	1	0	14
Hasson	6	24/05/2006	22:51	4	2	15
Hooker	6	24/05/2006	21:13	0	0	14
McIntosh	6	24/05/2006	22:51	1	0	15
Pamkoski	6	24/05/2006	21:23	0	0	14
Popoff	6	24/05/2006	21:52	1	0	15
Robertson	6	24/05/2006	21:28	3	1	14
Trailer	6	24/05/2006	21:53	2	1	14
Veltkamp	6	24/05/2006	22:29	4	2	15
Venema	6	24/05/2006	21:40	2	1	14
Vol	6	24/05/2006	22:22	1	0	15
Wilson	6	24/05/2006	22:13	5	2	15
Zeron	6	24/05/2006	22:17	3	2	14
Beauregard	6	25/05/2006	21:11	0	1	20
Brouseville	6	25/05/2006	21:30	0	0	16
Corner	6	25/05/2006	21:55	0	0	17
Ferguson_1	6	25/05/2006	21:47	0	1	20
Ferguson_2	6	25/05/2006	21:30	0	1	20
Godwin	6	25/05/2006	22:40	0	1	15
Luther	6	25/05/2006	21:17	0	1	18
McKenzie	6	25/05/2006	22:18	1	1	20
Rooney	6	25/05/2006	22:55	0	0	15
Rost	6	25/05/2006	21:03	0	1	19
Sayean	6	25/05/2006	20:22	1	0	16
Smith	6	25/05/2006	20:05	1	0	18
Sneath	6	25/05/2006	22:32	1	1	20
UpperCanada	6	25/05/2006	22:03	0	1	20
Wagemans_1	6	25/05/2006	22:58	1	1	19
Wagemans_2	6	25/05/2006	22:47	0	1	19
Wyands	6	25/05/2006	21:42	0	1	17
Barkley	7	18/06/2006	22:16	2	0	25
Bilmer	7	18/06/2006	22:30	1	0	25
Burles	7	18/06/2006	21:42	1	0	25
English	7	18/06/2006	22:58	2	0	20
Gervais	7	18/06/2006	22:28	1	0	20
GravelPit	7	18/06/2006	23:58	1	0	20
Hasson	7	18/06/2006	22:50	2	0	20
Hooker	7	18/06/2006	22:17	1	0	25
McIntosh	7	18/06/2006	23:06	1	0	20
Pamkoski	7	18/06/2006	22:02	1	0	25
Popoff	7	18/06/2006	21:25	2	0	26
Robertson	7	18/06/2006	22:05	1	1	25

Trailer	7	18/06/2006	21:43	2	1	25
Veltkamp	7	18/06/2006	23:08	3	0	20
Venema	7	18/06/2006	21:56	2	1	25
Vol	7	18/06/2006	23:32	1	0	20
Wilson	7	18/06/2006	21:27	4	1	26
Zeron	7	18/06/2006	23:18	2	0	20
Beauregard	7	19/06/2006	22:15	3	0	22
Brouseville	7	19/06/2006	22:04	2	1	22
Corner	7	19/06/2006	21:32	2	1	22
Dafoe	7	19/06/2006	21:01	4	0	22
Fergusen_1	7	19/06/2006	21:45	2	0	22
Fergusen_2	7	19/06/2006	22:01	4	0	22
Godwin	7	19/06/2006	23:19	1	1	20
Luther	7	19/06/2006	22:21	1	1	22
McKenzie	7	19/06/2006	23:15	2	0	20
Rooney	7	19/06/2006	21:57	1	1	21
Rost	7	19/06/2006	22:33	1	1	21
Sayean	7	19/06/2006	23:42	1	1	20
Smith	7	19/06/2006	23:55	3	0	18
Sneath	7	19/06/2006	22:59	3	0	20
UpperCanada	7	19/06/2006	21:29	3	0	22
Wagemans_1	7	19/06/2006	22:30	4	0	21
Wagemans_2	7	19/06/2006	22:46	3	0	21
Wyands	7	19/06/2006	21:45	3	1	22
Barkley	8	12/07/2006	22:30	1	0	22
Bilmer	8	12/07/2006	22:43	0	0	22
Burles	8	12/07/2006	23:18	0	0	19
Dafoe	8	12/07/2006	21:51	1	2	21
English	8	12/07/2006	21:38	1	1	23
Gervais	8	12/07/2006	22:18	0	1	21
GravelPit	8	12/07/2006	21:15	2	2	20
Hasson	8	12/07/2006	21:53	1	1	21
Hooker	8	12/07/2006	22:54	1	1	21
McIntosh	8	12/07/2006	22:10	1	1	22
Pamkoski	8	12/07/2006	23:06	1	1	20
Popoff	8	12/07/2006	23:33	0	0	18
Robertson	8	12/07/2006	22:40	2	0	22
Trailer	8	12/07/2006	23:01	1	1	20
Veltkamp	8	12/07/2006	21:27	1	2	23
Venema	8	12/07/2006	22:51	1	1	21
Vol	8	12/07/2006	21:35	0	2	23
Wilson	8	12/07/2006	23:20	2	1	19
Zeron	8	12/07/2006	21:15	2	1	20
Beauregard	8	13/07/2006	22:19	1	0	25
Brouseville	8	13/07/2006	23:01	0	0	24
Corner	8	13/07/2006	23:22	2	0	24
Fergusen_1	8	13/07/2006	22:48	1	0	24
Fergusen_2	8	13/07/2006	22:33	1	0	24
Godwin	8	13/07/2006	21:44	0	0	25
Luther	8	13/07/2006	22:47	0	0	24
McKenzie	8	13/07/2006	21:15	1	0	26
Rooney	8	13/07/2006	22:10	0	0	25
Rost	8	13/07/2006	22:35	0	0	24
Sayean	8	13/07/2006	21:29	1	0	26
Smith	8	13/07/2006	21:15	1	0	26

Sneath	8	13/07/2006	21:32	1	0	26
UpperCanada	8	13/07/2006	23:06	1	0	24
Wagemans_1	8	13/07/2006	22:00	3	0	25
Wagemans_2	8	13/07/2006	21:47	2	0	25
Wyands	8	13/07/2006	23:12	0	0	24
Barkley	4 - redone	25/04/2006	21:40	0	0	2
Bilmer	4 - redone	25/04/2006	21:56	0	0	1
Burles	4 - redone	25/04/2006	22:31	0	0	0
Dafoe	4 - redone	25/04/2006	21:06	0	0	0
English	4 - redone	25/04/2006	20:53	0	0	4
Gervais	4 - redone	25/04/2006	21:30?	0	0	2
GravelPit	4 - redone	25/04/2006	20:31	0	0	2
Hasson	4 - redone	25/04/2006	21:05	0	0	1
Hooker	4 - redone	25/04/2006	22:06	0	0	0
McIntosh	4 - redone	25/04/2006	21:27	0	0	0
Pamkoski	4 - redone	25/04/2006	22:19	0	0	-1
Popoff	4 - redone	25/04/2006	22:44	0	0	-1
Robertson	4 - redone	25/04/2006	21:50	0	0	2
Trailer	4 - redone	25/04/2006	22:19	0	0	3
Veltkamp	4 - redone	25/04/2006	20:42	0	0	4
Venema	4 - redone	25/04/2006	22:03	0	0	2
Vol	4 - redone	25/04/2006	20:52	0	0	2
Wilson	4 - redone	25/04/2006	22:33	0	0	2
Zeron	4 - redone	25/04/2006	20:25	0	0	4
Bilmer	V1	01/05/2006	16:00	3	0	26
Burles	V1	01/05/2006	14:32	4	0	23
Dafoe	V1	01/05/2006	12:23	2	0	25
GravelPit	V1	01/05/2006	13:40	2	0	24
Hooker	V1	01/05/2006	15:24	2	0	25
McIntosh	V1	01/05/2006	11:20	2	0	25
Pamkoski	V1	01/05/2006	15:15	4	0	23
Popoff	V1	01/05/2006	14:02	4	0	28
Vol	V1	01/05/2006	13:09	2	0	24
Wagemans_1	V1	01/05/2006	16:40	4	0	23
Beauregard	V1	04/05/2006	15:06	5	1	
Fergusen_1	V1	04/05/2006	13:52	4	1	
Fergusen_2	V1	04/05/2006	14:21	5	1	
McKenzie	V1	04/05/2006	12:07	2	0	
Sneath	V1	04/05/2006	11:38	1	0	
UpperCanada	V1	04/05/2006	13:20	4	1	
Wagemans_2	V1	04/05/2006	10:22	3	0	
English	V1	05/05/2006	10:43	2	1	18
Hasson	V1	05/05/2006	10:14	0	0	16
Veltkamp	V1	05/05/2006	11:40	1	1	20
Wilson	V1	05/05/2006	12:49	3	1	20
Zeron	V1	05/05/2006	12:30	3	1	20
Barkley	V1	08/05/2006	13:58	2	0	20
Gervais	V1	08/05/2006	14:18	0	0	20
Godwin	V1	08/05/2006	17:22	0	0	20
Robertson	V1	08/05/2006	13:22	1	0	24
Rooney	V1	08/05/2006	15:20	1	0	24
Sayean	V1	08/05/2006	11:45	2	1	24
Trailer	V1	08/05/2006	11:26	1	0	22
Venema	V1	08/05/2006	12:54	1	0	22
Brouseville	V1	09/05/2006	14:27	4	1	20

Corner	V1	09/05/2006	13:40	3	1	24
Luther	V1	09/05/2006	14:45	4	1	20
Rost	V1	09/05/2006	15:36	2	1	20
Smith	V1	09/05/2006	13:04	2	1	24
Wyands	V1	09/05/2006	13:58	4	1	20
Barkley	V2	24/05/2006	16:47	1	1	24
Bilmer	V2	24/05/2006	11:34	1	0	18
Burles	V2	24/05/2006	12:50	1	0	18
Dafoe	V2	24/05/2006	14:28	2	0	21
Gervais	V2	24/05/2006	16:25	1	1	24
GravelPit	V2	24/05/2006	13:42	0	0	21
Hooker	V2	24/05/2006	12:04	1	0	18
Luther	V2	24/05/2006	16:47	3	0	26
McIntosh	V2	24/05/2006	15:02	0	0	21
Pamkoski	V2	24/05/2006	12:18	1	0	18
Popoff	V2	24/05/2006	13:10	0	0	21
Robertson	V2	24/05/2006	17:00	2	1	24
Rost	V2	24/05/2006	16:29	3	0	26
Venema	V2	24/05/2006	17:37	1	1	22
Vol	V2	24/05/2006	14:06	2	0	21
English	V2	25/05/2006	15:22	3	0	27
Hasson	V2	25/05/2006	16:05	2	0	27
Trailer	V2	25/05/2006	11:34	2	0	23
Veltkamp	V2	25/05/2006	13:46	2	0	27
Wilson	V2	25/05/2006	13:04	3	0	23
Zeron	V2	25/05/2006	13:23	3	0	25
Brouseville	V2	28/05/2006	11:41	1	1	25
Corner	V2	28/05/2006	12:25	1	1	25
Godwin	V2	28/05/2006	14:03	2	1	25
Sayean	V2	28/05/2006	12:51	1	1	25
Wyands	V2	28/05/2006	12:00	1	1	25
Beauregard	V2	29/05/2006	12:47	1	1	26
Ferguson_1	V2	29/05/2006	14:04	1	1	26
Ferguson_2	V2	29/05/2006	13:30	1	1	26
McKenzie	V2	29/05/2006	15:12	0	1	29
Rooney	V2	29/05/2006	10:18	0	1	25
Smith	V2	29/05/2006	09:59	1	1	24
Sneath	V2	29/05/2006	16:26	0	1	29
UpperCanada	V2	29/05/2006	14:45	2	1	26
Wagemans_1	V2	30/05/2006	11:40	1	1	27
Wagemans_2	V2	30/05/2006	10:30	0	1	27
Brouseville	V3	14/06/2006	17:03	2	1	23
Corner	V3	14/06/2006	16:23	4	1	26
Godwin	V3	14/06/2006	14:07	2	1	26
Rooney	V3	14/06/2006	11:40	2	1	26
Sayean	V3	14/06/2006	14:42	2	1	26
Smith	V3	14/06/2006	15:58	2	1	26
Wyands	V3	14/06/2006	16:40	4	1	23
English	V3	15/06/2006	12:25	2	1	20
Luther	V3	15/06/2006	10:34	3	1	25
Trailer	V3	15/06/2006	15:50	4	1	20
Veltkamp	V3	15/06/2006	14:08	3	1	20
Venema	V3	15/06/2006	17:00	2	1	20
Wilson	V3	15/06/2006	15:19	2	1	20
Zeron	V3	15/06/2006	14:51	2	1	20

Bilmer	V3	16/06/2006	16:32	1	1	25
Burles	V3	16/06/2006	14:57	4	1	25
Dafoe	V3	16/06/2006	12:50	2	0	25
Gervais	V3	16/06/2006	11:05	1	0	25
GravelPit	V3	16/06/2006	14:05	2	1	25
Hooker	V3	16/06/2006	16:13	3	0	25
McIntosh	V3	16/06/2006	11:55	2	0	25
Popoff	V3	16/06/2006	14:31	2	1	25
Robertson	V3	16/06/2006	10:25	1	0	25
Vol	V3	16/06/2006	13:35	2	1	25
Barkley	V3	17/06/2006	16:05	3	2	20
McKenzie	V3	17/06/2006	16:28	1	1	20
Sneath	V3	17/06/2006	14:57	2	1	20
Wagemans_1	V3	17/06/2006	12:50	3	1	20
Wagemans_2	V3	17/06/2006	13:45	2	1	20
Hasson	V3	19/06/2006	12:01	2	1	20
Pamkoski	V3	19/06/2006	15:48	2	1	25
Rost	V3	19/06/2006	11:38	4	1	25
Beauregard	V3	21/06/2006	11:59	2	1	20
Fergusen_1	V3	21/06/2006	11:08	2	1	20
Fergusen_2	V3	21/06/2006	11:32	3	1	20
UpperCanada	V3	21/06/2006	10:45	2	1	20
Barkley	V4	05/07/2006	11:38	3	1	22
Gervais	V4	05/07/2006	11:20	2	1	22
Robertson	V4	05/07/2006	12:00	2	1	22
Trailer	V4	05/07/2006	13:27	2	1	24
Veltkamp	V4	05/07/2006	15:24	2	1	24
Venema	V4	05/07/2006	13:01	2	1	24
Wilson	V4	05/07/2006	14:38	3	1	24
Zeron	V4	05/07/2006	15:00	2	1	24
Bilmer	V4	06/07/2006	12:43	2	1	20
Burles	V4	06/07/2006	13:52	2	1	22
Dafoe	V4	06/07/2006	15:29	2	1	23
English	V4	06/07/2006	10:19	2	1	21
GravelPit	V4	06/07/2006	14:41	3	1	24
Hasson	V4	06/07/2006	11:15	3	1	21
Hooker	V4	06/07/2006	13:08	2	1	20
McIntosh	V4	06/07/2006	16:15	2	1	23
Pamkoski	V4	06/07/2006	13:30	2	1	21
Popoff	V4	06/07/2006	14:21	3	1	23
Vol	V4	06/07/2006	15:04	2	1	24
Brouseville	V4	07/07/2006	11:47	1	0	24
Corner	V4	07/07/2006	12:20	1	0	27
Godwin	V4	07/07/2006	14:00	1	1	27
Luther	V4	07/07/2006	10:57	2	0	23
Rooney	V4	07/07/2006	14:53	1	0	29
Rost	V4	07/07/2006	10:34	1	0	23
Sayean	V4	07/07/2006	13:03	2	0	27
Smith	V4	07/07/2006	12:36	3	0	27
Wyands	V4	07/07/2006	12:03	2	0	25
Beauregard	V4	08/07/2006	10:35	1	0	25
Fergusen_1	V4	08/07/2006	11:39	1	0	26
Fergusen_2	V4	08/07/2006	11:04	1	0	26
McKenzie	V4	08/07/2006	12:35	2	0	26
Sneath	V4	08/07/2006	13:59	1	0	29

UpperCanada	V4	08/07/2006	12:05	1	0	26
Wagemans_1	V4	08/07/2006	15:25	2	0	29
Wagemans_2	V4	08/07/2006	14:33	1	0	29
Bilmer	v5leopardfrogs	17/07/2006	Not recorded	Not recorded	Not recorded	Not recorded
Brouseville	v5leopardfrogs	17/07/2006	Not recorded	Not recorded	Not recorded	Not recorded
Burles	v5leopardfrogs	17/07/2006	Not recorded	Not recorded	Not recorded	Not recorded
Corner	v5leopardfrogs	17/07/2006	Not recorded	Not recorded	Not recorded	Not recorded
Dafoe	v5leopardfrogs	17/07/2006	Not recorded	Not recorded	Not recorded	Not recorded
English	v5leopardfrogs	17/07/2006	Not recorded	Not recorded	Not recorded	Not recorded
Godwin	v5leopardfrogs	17/07/2006	Not recorded	Not recorded	Not recorded	Not recorded
GravelPit	v5leopardfrogs	17/07/2006	Not recorded	Not recorded	Not recorded	Not recorded
Hasson	v5leopardfrogs	17/07/2006	Not recorded	Not recorded	Not recorded	Not recorded
Hooker	v5leopardfrogs	17/07/2006	Not recorded	Not recorded	Not recorded	Not recorded
Luther	v5leopardfrogs	17/07/2006	Not recorded	Not recorded	Not recorded	Not recorded
McIntosh	v5leopardfrogs	17/07/2006	Not recorded	Not recorded	Not recorded	Not recorded
Pamkoski	v5leopardfrogs	17/07/2006	Not recorded	Not recorded	Not recorded	Not recorded
Popoff	v5leopardfrogs	17/07/2006	Not recorded	Not recorded	Not recorded	Not recorded
Rooney	v5leopardfrogs	17/07/2006	Not recorded	Not recorded	Not recorded	Not recorded
Rost	v5leopardfrogs	17/07/2006	Not recorded	Not recorded	Not recorded	Not recorded
Sayean	v5leopardfrogs	17/07/2006	Not recorded	Not recorded	Not recorded	Not recorded
Smith	v5leopardfrogs	17/07/2006	Not recorded	Not recorded	Not recorded	Not recorded
Trailer	v5leopardfrogs	17/07/2006	Not recorded	Not recorded	Not recorded	Not recorded
Veltkamp	v5leopardfrogs	17/07/2006	Not recorded	Not recorded	Not recorded	Not recorded
Vol	v5leopardfrogs	17/07/2006	Not recorded	Not recorded	Not recorded	Not recorded
Wilson	v5leopardfrogs	17/07/2006	Not recorded	Not recorded	Not recorded	Not recorded
Wyands	v5leopardfrogs	17/07/2006	Not recorded	Not recorded	Not recorded	Not recorded
Zeron	v5leopardfrogs	17/07/2006	Not recorded	Not recorded	Not recorded	Not recorded
Barkley	v5leopardfrogs	20/07/2006	Not recorded	Not recorded	Not recorded	Not recorded
Beauregard	v5leopardfrogs	20/07/2006	Not recorded	Not recorded	Not recorded	Not recorded
Ferguson_1	v5leopardfrogs	20/07/2006	Not recorded	Not recorded	Not recorded	Not recorded
Ferguson_2	v5leopardfrogs	20/07/2006	Not recorded	Not recorded	Not recorded	Not recorded
Gervais	v5leopardfrogs	20/07/2006	Not recorded	Not recorded	Not recorded	Not recorded
McKenzie	v5leopardfrogs	20/07/2006	Not recorded	Not recorded	Not recorded	Not recorded
Robertson	v5leopardfrogs	20/07/2006	Not recorded	Not recorded	Not recorded	Not recorded
Sneath	v5leopardfrogs	20/07/2006	Not recorded	Not recorded	Not recorded	Not recorded

UpperCanada	v5leopardfrogs	20/07/2006	Not recorded	Not recorded	Not recorded	Not recorded
Venema	v5leopardfrogs	20/07/2006	Not recorded	Not recorded	Not recorded	Not recorded
Wagemans_1	v5leopardfrogs	20/07/2006	Not recorded	Not recorded	Not recorded	Not recorded
Wagemans_2	v5leopardfrogs	20/07/2006	Not recorded	Not recorded	Not recorded	Not recorded

2006 Field Data Chapters 3 & 4 - Call Surveys - Calling directly at pond

NOTE: Survey 4 - redone was not used in the analysis

Species are: Species: WDF = Wood frog, WCF = Western chorus frog; SPP = Spring peeper; NLF = Northern leopard frog; AMT = American toad; GTF = Gray treefrog; GRF = Green frog; MIF = Mink frog; BUF = Bull frog.

Calling activity for each species

- 0** no individuals calling
- 1** individual(s) can be counted, calls are not overlapping
- 2** calls of <15 individuals can be distinguished, but there is some overlapping
- 3** calls of ≥ 15 individuals

Pondname	Survey	WDF	WCF	SPP	AMT	NLF	GTF	GRF	BUF
Beauregard	1		1						
Brouseville	1								
Corner	1								
Ferguson_1	1								
Ferguson_2	1								
Godwin	1								
Luther	1	3		3					
McKenzie	1								
Rooney	1								
Rost	1								
Sayean	1			3					
Smith	1								
Sneath	1								
UpperCanada	1								
Wagemans_1	1								
Wagemans_2	1								
Wyands	1								
Barkley	1								
Bilmer	1								
Burles	1								
Dafoe	1			2					
English	1								
Gervais	1								
GravelPit	1								
Hasson	1								
Hooker	1								
McIntosh	1		3						
Pamkoski	1								
Popoff	1								
Robertson	1								
Trailer	1								
Veltkamp	1								
Venema	1								
Vol	1								
Wilson	1								
Zeron	1								

Beauregard	2								
Brouseville	2			1					
Corner	2								
Ferguson_1	2								
Ferguson_2	2								
Godwin	2					1			
Luther	2	3		3					
McKenzie	2								
Rooney	2								
Rost	2	2		2		1			
Sayean	2	3		3					
Smith	2	1							
Sneath	2								
UpperCanada	2								
Wagemans_1	2								
Wagemans_2	2								
Wyands	2								
Barkley	2								
Bilmer	2	2		3					
Burles	2			3					
Dafoe	2			3					
English	2								
Gervais	2								
GravelPit	2								
Hasson	2			2					
Hooker	2								
McIntosh	2	2	2	3					
Pamkoski	2			3					
Popoff	2								
Robertson	2								
Trailer	2								
Veltkamp	2	3		3					
Venema	2								
Vol	2								
Wilson	2								
Zeron	2								
Barkley	3								
Bilmer	3			3		1			
Burles	3			3					
Dafoe	3			3		2			
English	3				2	1			
Gervais	3								
GravelPit	3			1					
Hasson	3			2					
Hooker	3					1			
McIntosh	3	1	1	3		1			
Pamkoski	3			3					
Popoff	3								
Robertson	3								
Trailer	3			1					
Veltkamp	3			3		1			
Venema	3								
Vol	3								
Wilson	3								
Zeron	3								

Beauregard	3	1	1			1			
Brouseville	3			2		1			
Corner	3			1	1				
Ferguson_1	3								
Ferguson_2	3								
Godwin	3			1		1			
Luther	3			3		1			
McKenzie	3			1		1			
Rooney	3			1					
Rost	3	1		2					
Sayean	3			3		1			
Smith	3								
Sneath	3					1			
UpperCanada	3				1				
Wagemans_1	3					1			
Wagemans_2	3			2					
Wyands	3								
Beauregard	4								
Brouseville	4			1					
Corner	4			1					
Ferguson_1	4								
Ferguson_2	4								
Godwin	4			2		1			
Luther	4			3		1			
McKenzie	4								
Rooney	4								
Rost	4			3					
Sayean	4			3	1				
Smith	4								
Sneath	4								
UpperCanada	4								
Wagemans_1	4								
Wagemans_2	4								
Wyands	4								
Barkley	4								
Bilmer	4			2		1			
Burles	4			2					
Dafoe	4			3					
English	4								
Gervais	4								
GravelPit	4			2					
Hasson	4			3					
Hooker	4								
McIntosh	4	1	1	3		1			
Pamkoski	4			3					
Popoff	4								
Robertson	4								
Trailer	4								
Veltkamp	4			3					
Venema	4								
Vol	4		1						
Wilson	4								
Zeron	4								
Barkley	5								
Beauregard	5		1	1	1				

English	5			1					
Ferguson_1	5								
Ferguson_2	5			2					
Gervais	5				1				
Hasson	5			3					
McKenzie	5								
Robertson	5								
Sneath	5								
Trailer	5								
UpperCanada	5			1					
Veltkamp	5			3	1				
Venema	5			1					
Wagemans_1	5								
Wagemans_2	5								
Wilson	5				2				
Zeron	5								
Bilmer	5			1					
Brouseville	5			1					
Burles	5			1	1				
Corner	5			1					
Dafoe	5			3	1	1			
Godwin	5			2					
GravelPit	5			1	1				
Hooker	5								
Luther	5			3			1		
McIntosh	5			3	1				
Pamkoski	5			2	1				
Popoff	5				2				
Rooney	5								
Rost	5			2					
Sayean	5			3					
Smith	5								
Vol	5			1					
Wyands	5								
Barkley	6								
Bilmer	6			1			3		
Burles	6			1			3		
Dafoe	6						1		
English	6								
Gervais	6								
GravelPit	6			1					
Hasson	6								
Hooker	6								
McIntosh	6			1			2	1	
Pamkoski	6			1			1	1	
Popoff	6							1	
Robertson	6								
Trailer	6								
Veltkamp	6			1			2		
Venema	6			1	1		2		
Vol	6						1		
Wilson	6								
Zeron	6				1				
Beauregard	6				1		1		
Brouseville	6			2	1		1		

Corner	6								
Ferguson_1	6			1				1	
Ferguson_2	6								
Godwin	6			1					
Luther	6			1			3		
McKenzie	6								
Rooney	6								
Rost	6						2		
Sayean	6						3	1	
Smith	6							1	
Sneath	6								
UpperCanada	6				1				
Wagemans_1	6								
Wagemans_2	6			1			1		
Wyands	6				1				
Barkley	7							1	
Bilmer	7						2	1	
Burles	7						1	1	
English	7							2	2
Gervais	7							1	
GravelPit	7						1	1	
Hasson	7							1	
Hooker	7							2	
McIntosh	7						3	3	
Pamkoski	7						2	2	
Popoff	7							2	
Robertson	7							1	
Trailer	7							2	
Veltkamp	7						2	1	
Venema	7						3	1	
Vol	7							1	
Wilson	7							1	
Zeron	7							2	
Beauregard	7							1	
Brouseville	7						1		
Corner	7							1	
Dafoe	7						1	1	
Ferguson_1	7							1	
Ferguson_2	7								1
Godwin	7						1	2	
Luther	7						3	1	
McKenzie	7							2	1
Rooney	7							1	1
Rost	7						2		
Sayean	7						2	2	
Smith	7							1	
Sneath	7						1	1	
UpperCanada	7						1		
Wagemans_1	7							1	
Wagemans_2	7							2	1
Wyands	7								
Barkley	8							1	
Bilmer	8							1	
Burles	8							1	
Dafoe	8								

English	8							2	1
Gervais	8								
GravelPit	8							1	
Hasson	8							1	
Hooker	8							1	
McIntosh	8							1	
Pamkoski	8							1	
Popoff	8							1	
Robertson	8							1	
Trailer	8							2	
Veltkamp	8								
Venema	8						1	1	
Vol	8								
Wilson	8							1	
Zeron	8							1	
Beauregard	8							1	
Brouseville	8								
Corner	8							1	
Ferguson_1	8							1	
Ferguson_2	8							1	1
Godwin	8								
Luther	8								
McKenzie	8							1	1
Rooney	8							2	1
Rost	8								
Sayean	8							1	
Smith	8							1	
Sneath	8							1	
UpperCanada	8							1	
Wagemans_1	8							1	
Wagemans_2	8							1	1
Wyands	8							1	
Barkley	4 - redone								
Bilmer	4 - redone			3					
Burles	4 - redone			2					
Dafoe	4 - redone			3					
English	4 - redone								
Gervais	4 - redone								
GravelPit	4 - redone			1					
Hasson	4 - redone			3					
Hooker	4 - redone								
McIntosh	4 - redone	1	1	3		1			
Pamkoski	4 - redone			3					
Popoff	4 - redone								
Robertson	4 - redone								
Trailer	4 - redone								
Veltkamp	4 - redone			3					
Venema	4 - redone								
Vol	4 - redone		1						
Wilson	4 - redone								
Zeron	4 - redone								

2006 Field Data Chapters 3 & 4 - Call Surveys - Calling within 100 m of pond edge

NOTE: Survey 4 - redone was not used in the analysis

Species are: Species: WDF = Wood frog, WCF = Western chorus frog; SPP = Spring peeper; NLF = Northern leopard frog; AMT = American toad; GTF = Gray treefrog; GRF = Green frog; MIF = Mink frog; BUF = Bull frog.

Calling activity for each species

- 0** no individuals calling
- 1** individual(s) can be counted, calls are not overlapping
- 2** calls of <15 individuals can be distinguished, but there is some overlapping
- 3** calls of ≥ 15 individuals

Pondname	Survey	WDF	WCF	SPP	AMT	NLF	GTF	GRF	BUF
Beauregard	1		1	2					
Brouseville	1								
Corner	1								
Ferguson_1	1		1	1					
Ferguson_2	1		1	1					
Godwin	1								
Luther	1								
McKenzie	1			1					
Rooney	1								
Rost	1								
Sayean	1								
Smith	1								
Sneath	1								
UpperCanada	1								
Wagemans_1	1								
Wagemans_2	1								
Wyands	1								
Barkley	1								
Bilmer	1								
Burles	1								
Dafoe	1								
English	1								
Gervais	1	1	1						
GravelPit	1								
Hasson	1			2					
Hooker	1								
McIntosh	1								
Pamkoski	1								
Popoff	1								
Robertson	1								
Trailer	1								
Veltkamp	1		1	1					
Venema	1								
Vol	1								
Wilson	1								
Zeron	1			1					
Beauregard	2	1	1	1					
Brouseville	2								

Corner	2			1					
Ferguson_1	2								
Ferguson_2	2								
Godwin	2								
Luther	2	3	1						
McKenzie	2	1		3					
Rooney	2			3					
Rost	2	3	1	3					
Sayean	2			3					
Smith	2	2							
Sneath	2	2	1	1					
UpperCanada	2			3					
Wagemans_1	2			1					
Wagemans_2	2			1					
Wyands	2								
Barkley	2								
Bilmer	2								
Burles	2								
Dafoe	2				1				
English	2	1							
Gervais	2								
GravelPit	2								
Hasson	2	1							
Hooker	2								
McIntosh	2								
Pamkoski	2								
Popoff	2	2		3					
Robertson	2								
Trailer	2								
Veltkamp	2								
Venema	2								
Vol	2		1	3					
Wilson	2								
Zeron	2								
Barkley	3								
Bilmer	3				1				
Burles	3				1	1			
Dafoe	3								
English	3	1		3	1				
Gervais	3		1	2	2				
GravelPit	3								
Hasson	3	1		2					
Hooker	3								
McIntosh	3								
Pamkoski	3								
Popoff	3				1				
Robertson	3								
Trailer	3			1					
Veltkamp	3	1							
Venema	3				2				
Vol	3			1	1				
Wilson	3			1					
Zeron	3			1	1				
Beauregard	3			2					
Brouseville	3								

Corner	3			3					
Fergusen_1	3								
Fergusen_2	3		1						
Godwin	3								
Luther	3				3				
McKenzie	3			3					
Rooney	3								
Rost	3								
Sayean	3								
Smith	3								
Sneath	3		2	3		1			
UpperCanada	3				1				
Wagemans_1	3			3					
Wagemans_2	3								
Wyands	3								
Beauregard	4		1						
Brouseville	4								
Corner	4								
Fergusen_1	4								
Fergusen_2	4								
Godwin	4								
Luther	4								
McKenzie	4		1	3					
Rooney	4								
Rost	4								
Sayean	4								
Smith	4			1					
Sneath	4		1						
UpperCanada	4								
Wagemans_1	4								
Wagemans_2	4			1					
Wyands	4								
Barkley	4								
Bilmer	4			3					
Burles	4								
Dafoe	4					1			
English	4								
Gervais	4								
GravelPit	4								
Hasson	4								
Hooker	4								
McIntosh	4								
Pamkoski	4								
Popoff	4			1					
Robertson	4								
Trailer	4								
Veltkamp	4								
Venema	4			1					
Vol	4			3					
Wilson	4								
Zeron	4								
Barkley	5								
Beauregard	5								
English	5				2				
Fergusen_1	5			2					

Ferguson_2	5								
Gervais	5								
Hasson	5				1				
McKenzie	5				3				
Robertson	5								
Sneath	5			3		1			
Trailer	5								
UpperCanada	5			2	1				
Veltkamp	5								
Venema	5			1	1				
Wagemans_1	5			3					
Wagemans_2	5			1					
Wilson	5								
Zeron	5				1				
Bilmer	5			1	2				
Brouseville	5								
Burles	5			2	1				
Corner	5								
Dafoe	5								
Godwin	5				1				
GravelPit	5								
Hooker	5				1				
Luther	5								
McIntosh	5								
Pamkoski	5				1				
Popoff	5								
Rooney	5			1					
Rost	5								
Sayean	5				2				
Smith	5			1	1				
Vol	5			3	1				
Wyands	5								
Barkley	6								
Bilmer	6								
Burles	6								
Dafoe	6				1				
English	6								
Gervais	6								
GravelPit	6								
Hasson	6								
Hooker	6								
McIntosh	6								
Pamkoski	6						2		
Popoff	6								
Robertson	6								
Trailer	6								
Veltkamp	6								
Venema	6								
Vol	6			1	1		1		
Wilson	6								
Zeron	6								
Beauregard	6						2		
Brouseville	6								
Corner	6						1		
Ferguson_1	6								

Ferguson_2	6								
Godwin	6								
Luther	6								
McKenzie	6								
Rooney	6								
Rost	6								
Sayean	6			1					
Smith	6								
Sneath	6								
UpperCanada	6								
Wagemans_1	6						2		
Wagemans_2	6				1				
Wyands	6			2					
Barkley	7								
Bilmer	7								
Burles	7						2	1	
English	7								
Gervais	7								
GravelPit	7								
Hasson	7								
Hooker	7								
McIntosh	7								
Pamkoski	7								
Popoff	7								
Robertson	7								
Trailer	7								
Veltkamp	7								
Venema	7								
Vol	7						2	2	
Wilson	7								
Zeron	7								
Beauregard	7								
Brouseville	7				1		2		
Corner	7						1		
Dafoe	7								
Ferguson_1	7								
Ferguson_2	7								
Godwin	7							1	
Luther	7								
McKenzie	7								
Rooney	7								
Rost	7						1		
Sayean	7						1		
Smith	7						1		
Sneath	7								
UpperCanada	7								
Wagemans_1	7						1		
Wagemans_2	7								
Wyands	7								
Barkley	8								
Bilmer	8								
Burles	8							1	
Dafoe	8								
English	8								
Gervais	8								

GravelPit	8								
Hasson	8								
Hooker	8								
McIntosh	8								
Pamkoski	8								
Popoff	8								
Robertson	8								
Trailer	8								
Veltkamp	8								
Venema	8								
Vol	8								
Wilson	8								
Zeron	8								
Beauregard	8								
Brouseville	8								
Corner	8								
Ferguson_1	8								
Ferguson_2	8								
Godwin	8								
Luther	8								
McKenzie	8								
Rooney	8								
Rost	8								
Sayean	8								
Smith	8								
Sneath	8								
UpperCanada	8							1	
Wagemans_1	8								
Wagemans_2	8								
Wyands	8								
Barkley	4 - redone								
Bilmer	4 - redone								
Burles	4 - redone								
Dafoe	4 - redone								
English	4 - redone								
Gervais	4 - redone								
GravelPit	4 - redone			1					
Hasson	4 - redone								
Hooker	4 - redone								
McIntosh	4 - redone								
Pamkoski	4 - redone								
Popoff	4 - redone								
Robertson	4 - redone								
Trailer	4 - redone								
Veltkamp	4 - redone								
Venema	4 - redone								
Vol	4 - redone								
Wilson	4 - redone								
Zeron	4 - redone								

2006 Field Data Chapters 3 & 4 - Visual Surveys - Number of adult frogs

Species are: Species: WDF = Wood frog, WCF = Western chorus frog; SPP = Spring peeper; NLF = Northern leopard frog; AMT = American toad; GTF = Gray treefrog; GRF = Green frog; MIF = Mink frog; BUF = Bull frog. Unknown - unidentified adult frog

Pondname	Survey	Time taken for visual survey	WDF	WCF	SPP	AMT	NLF	GTF	GRF	BUF	MIF	Unknown
Bilmer	V1	16 minutes				1	1		0			2
Burles	V1	19 minutes				1	7		0			
Dafoe	V1	26 minutes							0			
GravelPit	V1	14 minutes							0			
Hooker	V1	11 minutes					1		4			1
McIntosh	V1	52 minutes				3	3		4			2
Pamkoski	V1	15 minutes					5		0			3
Popoff	V1	16 minutes					5		6			2
Vol	V1	12 minutes							0			
Wagemans_1	V1	48 minutes					5		0			5
Beauregard	V1	30 minutes							0			1
Ferguson_1	V1	28 minutes							0			
Ferguson_2	V1	36 minutes					3		0			1
McKenzie	V1	46 minutes					1		0			
Sneath	V1	21 minutes					3		0			1
UpperCanada	V1	20 minutes							0			
Wagemans_2	V1	1 hour 6 minutes				1	6		1			
English	V1	49 minutes					9		3	1		3
Hasson	V1	23 minutes				5	2		0			4
Veltkamp	V1	36 minutes				1	7		4	1		
Wilson	V1	22 minutes				25			1			1
Zeron	V1	14 minutes							0			1
Barkley	V1	10 minutes					1		0			1
Gervais	V1	20 minutes					7		14			4
Godwin	V1	12 minutes					5		6			3
Robertson	V1	24 minutes					3		0			
Rooney	V1	1 hour 48 minutes							3		5	3
Sayean	V1	1 hour 10 minutes	12				7		31		2	17
Trailer	V1	1 hour 6 minutes					1		14			7
Venema	V1	16 minutes							5			2
Brouseville	V1	7 minutes							2			
Corner	V1	11 minutes				1	3		2			
Luther	V1	44 minutes				1	4		1			
Rost	V1	8 minutes	1				4		0			1
Smith	V1	24 minutes					7		29	4	1	1
Wyands	V1	18 minutes					1		3			
Barkley	V2	5 minutes					1		2			2
Bilmer	V2	17 minutes	1				1		4			
Burles	V2	12 minutes							0			
Dafoe	V2	22 minutes							0			
Gervais	V2	10 minutes					1		0			
GravelPit	V2	11 minutes							0			
Hooker	V2	8 minutes							2			1

Luther	V2	46 minutes					1		5			
McIntosh	V2	37 minutes							46			17
Pamkoski	V2	28 minutes					3		3			4
Popoff	V2	13 minutes					1		5			
Robertson	V2	23 minutes							0			1
Rost	V2	9 minutes				1			1			1
Venema	V2	13 minutes							4			
Vol	V2	9 minutes							0			
English	V2	36 minutes					3		5			4
Hasson	V2	11 minutes							1			2
Trailer	V2	1 hour 22 minutes							10			4
Veltkamp	V2	34 minutes					2		3			
Wilson	V2	14 minutes							1			
Zeron	V2	15 minutes							0			
Brouseville	V2	2 minutes							1			
Corner	V2	10 minutes							0			1
Godwin	V2	8 minutes							12			
Sayean	V2	58 minutes				1			39		1	10
Wyands	V2	15 minutes							8			2
Beauregard	V2	41 minutes							14			4
Ferguson_1	V2	24 minutes							4			1
Ferguson_2	V2	26 minutes							1			
McKenzie	V2	1 hour 3 minutes							3			2
Rooney	V2	1 hour 41 minutes							9		3	4
Smith	V2	6 minutes							6	3		2
Sneath	V2	15 minutes							4			3
UpperCanada	V2	16 minutes							0			
Wagemans_1	V2	39 minutes					11		9			6
Wagemans_2	V2	1 hour 1 minute					3		1			4
Brouseville	V3	3 minutes							0			1
Corner	V3	9 minutes							0			1
Godwin	V3	10 minutes					1		5			2
Rooney	V3	2 hours 1 minute							10	1	2	1
Sayean	V3	1 hour 2 minutes	1						34			6
Smith	V3	14 minutes							4	1		1
Wyands	V3	13 minutes							2			1
English	V3	40 minutes					4		7	1		2
Luther	V3	49 minutes							6			2
Trailer	V3	1 hour							5			2
Veltkamp	V3	35 minutes							9			1
Venema	V3	15 minutes							3			4
Wilson	V3	26 minutes							1			
Zeron	V3	18 minutes							1			1
Bilmer	V3	17 minutes	1						12			3
Burles	V3	23 minutes					1		2			
Dafoe	V3	35 minutes							3			3
Gervais	V3	13 minutes							0			4
GravelPit	V3	17 minutes							2			
Hooker	V3	10 minutes							14			2
McIntosh	V3	48 minutes							32			2
Popoff	V3	10 minutes							7			1
Robertson	V3	20 minutes							1			
Vol	V3	10 minutes							14			3
Barkley	V3	8 minutes							11			5

McKenzie	V3	49 minutes						6			2
Sneath	V3	18 minutes						6			
Wagemans_1	V3	44 minutes				7		14			6
Wagemans_2	V3	1 hour 1 minute						3			1
Hasson	V3	15 minutes				1		4			
Pamkoski	V3	17 minutes						18			2
Rost	V3	10 minutes				2		9			3
Beauregard	V3	30 minutes				1		4			
Ferguson_1	V3	19 minutes						1			
Ferguson_2	V3	22 minutes						1			
UpperCanada	V3	17 minutes						1			
Barkley	V4	14 minutes				2		24			6
Gervais	V4	10 minutes						3			2
Robertson	V4	26 minutes						0			1
Trailer	V4	1 hour 3 minutes						12			3
Veltkamp	V4	25 minutes						3			2
Venema	V4	17 minutes						25			1
Wilson	V4	17 minutes						3			
Zeron	V4	16 minutes						0			1
Bilmer	V4	17 minutes						7			2
Burles	V4	19 minutes						4			
Dafoe	V4	39 minutes						0			
English	V4	48 minutes						19	3		1
GravelPit	V4	12 minutes						1			
Hasson	V4	10 minutes						5			
Hooker	V4	15 minutes						21			2
McIntosh	V4	40 minutes						23			
Pamkoski	V4	16 minutes				1		23			1
Popoff	V4	16 minutes						11			
Vol	V4	11 minutes						5			3
Brouseville	V4	2 minutes						2			
Corner	V4	8 minutes						1			4
Godwin	V4	9 minutes						24			
Luther	V4	37 minutes						4			
Rooney	V4	1 hour 44 minutes						9		2	7
Rost	V4	14 minutes						28			6
Sayean	V4	44 minutes				1		18			
Smith	V4	20 minutes						6			3
Wyands	V4	10 minutes						8			1
Beauregard	V4	26 minutes						3			1
Ferguson_1	V4	20 minutes						0			
Ferguson_2	V4	25 minutes						1			
McKenzie	V4	47 minutes						0			2
Sneath	V4	24 minutes						6			1
UpperCanada	V4	18 minutes						0			
Wagemans_1	V4	47 minutes				2		12			8
Wagemans_2	V4	45 minutes						2			1

2006 Field Data Chapters 3 & 4 - Visual Surveys - Number of juvenile frogs

Species are: Species: WDF = Wood frog, WCF = Western chorus frog; SPP = Spring peeper; NLF = Northern leopard frog; AMT = American toad; GTF = Gray treefrog; GRF = Green frog; MIF = Mink frog; BUF = Bull frog.

Pondname	Survey	WDF	WCF	SPP	AMT	NLF	GTF	GRF	BUF	MIF
Bilmer	V1									
Burles	V1									
Dafoe	V1									
GravelPit	V1									
Hooker	V1									
McIntosh	V1							2		
Pamkoski	V1									
Popoff	V1									
Vol	V1									
Wagemans_1	V1					4				
Beauregard	V1									
Ferguson_1	V1									
Ferguson_2	V1					6				
McKenzie	V1									
Sneath	V1					1				
UpperCanada	V1									
Wagemans_2	V1					1				
English	V1							3		
Hasson	V1					1				
Veltkamp	V1									
Wilson	V1							1		
Zeron	V1									
Barkley	V1							1		
Gervais	V1									
Godwin	V1							3		
Robertson	V1									
Rooney	V1									
Sayean	V1							7		
Trailer	V1									
Venema	V1									
Brouseville	V1									
Corner	V1									
Luther	V1									
Rost	V1									
Smith	V1							6		
Wyands	V1									
Barkley	V2									
Bilmer	V2									
Burles	V2									
Dafoe	V2									
Gervais	V2									
GravelPit	V2									
Hooker	V2									
Luther	V2									
McIntosh	V2							1		
Pamkoski	V2									

Popoff	V2							2		
Robertson	V2									
Rost	V2									
Venema	V2									
Vol	V2									
English	V2					1				
Hasson	V2									
Trailer	V2							2		
Veltkamp	V2							1		
Wilson	V2									
Zeron	V2									
Brouseville	V2							1		
Corner	V2									
Godwin	V2							3		
Sayean	V2							11		
Wyands	V2									
Beauregard	V2									
Ferguson_1	V2									
Ferguson_2	V2					1				
McKenzie	V2									
Rooney	V2							2		
Smith	V2							2		
Sneath	V2									
UpperCanada	V2					1				
Wagemans_1	V2									
Wagemans_2	V2					3		2		
Brouseville	V3									
Corner	V3									
Godwin	V3									
Rooney	V3							1		
Sayean	V3							2		
Smith	V3									
Wyands	V3									
English	V3									
Luther	V3									
Trailer	V3									
Veltkamp	V3									
Venema	V3									
Wilson	V3									
Zeron	V3									
Bilmer	V3									
Burles	V3									
Dafoe	V3									
Gervais	V3									
GravelPit	V3									
Hooker	V3									
McIntosh	V3							1		
Popoff	V3									
Robertson	V3							1		
Vol	V3									
Barkley	V3									
McKenzie	V3									
Sneath	V3									
Wagemans_1	V3					1				
Wagemans_2	V3									

Hasson	V3									
Pamkoski	V3									
Rost	V3									
Beauregard	V3									
Ferguson_1	V3									
Ferguson_2	V3									
UpperCanada	V3									
Barkley	V4						1			
Gervais	V4									
Robertson	V4						2			
Trailer	V4									
Veltkamp	V4						1			
Venema	V4									
Wilson	V4									
Zeron	V4									
Bilmer	V4									
Burles	V4						2			
Dafoe	V4									
English	V4									
GravelPit	V4									
Hasson	V4						1			
Hooker	V4									
McIntosh	V4									
Pamkoski	V4									
Popoff	V4									
Vol	V4									
Brouseville	V4									
Corner	V4					1				
Godwin	V4									
Luther	V4									
Rooney	V4									
Rost	V4						1			
Sayean	V4									
Smith	V4								1	
Wyands	V4									
Beauregard	V4									
Ferguson_1	V4									
Ferguson_2	V4									
McKenzie	V4									
Sneath	V4									
UpperCanada	V4									
Wagemans_1	V4									
Wagemans_2	V4									

2006 Field Data Chapters 3 & 4 - Visual Surveys - Presence (1) of young of year frogs

NOTE: This data was only used in species richness calculations (i.e. species richness = sum of all presences (calling + adults in visual surveys + young frogs + young of year frogs))

NOTE: v5leopardfrogs is a separate visual survey to look for young of the year leopard frogs. This was not used in the analysis except for a 'presence' of this species. The methodology for v5 was to carefully survey the pond edges (especially promising areas such as wet grassland) for young-of year leopard frogs.

Species are: Species: WDF = Wood frog, WCF = Western chorus frog; SPP = Spring peeper; NLF = Northern leopard frog; AMT = American toad; GTF = Gray treefrog; GRF = Green frog; MIF = Mink frog; BUF = Bull frog.

Pondname	Survey	GRF	NLF	WDF	MIF	AMT
Bilmer	V1					
Burles	V1					
Dafoe	V1					
GravelPit	V1					
Hooker	V1					
McIntosh	V1					
Pamkoski	V1					
Popoff	V1					
Vol	V1					
Wagemans_1	V1					
Beauregard	V1					
Ferguson_1	V1					
Ferguson_2	V1					
McKenzie	V1					
Sneath	V1					
UpperCanada	V1					
Wagemans_2	V1					
English	V1					
Hasson	V1					
Veltkamp	V1					
Wilson	V1					
Zeron	V1					
Barkley	V1					
Gervais	V1					
Godwin	V1					
Robertson	V1					
Rooney	V1					
Sayean	V1					
Trailer	V1					
Venema	V1					
Brouseville	V1					
Corner	V1					
Luther	V1					
Rost	V1					

Smith	V1					
Wyands	V1					
Barkley	V2					
Bilmer	V2					
Burles	V2					
Dafoe	V2					
Gervais	V2					
GravelPit	V2					
Hooker	V2					
Luther	V2					
McIntosh	V2					
Pamkoski	V2					
Popoff	V2					
Robertson	V2					
Rost	V2					
Venema	V2					
Vol	V2					
English	V2					
Hasson	V2					
Trailer	V2					
Veltkamp	V2					
Wilson	V2					
Zeron	V2					
Brouseville	V2					
Corner	V2					
Godwin	V2					
Sayean	V2					
Wyands	V2					
Beauregard	V2					
Ferguson_1	V2					
Ferguson_2	V2					
McKenzie	V2					
Rooney	V2					
Smith	V2					
Sneath	V2					
UpperCanada	V2					
Wagemans_1	V2					
Wagemans_2	V2					
Brouseville	V3					
Corner	V3					
Godwin	V3					
Rooney	V3	1				
Sayean	V3	1				
Smith	V3					
Wyands	V3					
English	V3	1				
Luther	V3	1		1		
Trailer	V3	1				
Veltkamp	V3	1				
Venema	V3	1				
Wilson	V3					
Zeron	V3	1				
Bilmer	V3	1				
Burles	V3	1				
Dafoe	V3					

Gervais	V3					
GravelPit	V3	1				
Hooker	V3					
McIntosh	V3	1				
Popoff	V3	1				
Robertson	V3	1				
Vol	V3	1				
Barkley	V3					
McKenzie	V3	1				
Sneath	V3	1				
Wagemans_1	V3	1				
Wagemans_2	V3					
Hasson	V3	1				
Pamkoski	V3	1			1	
Rost	V3					
Beauregard	V3	1				
Ferguson_1	V3	1				
Ferguson_2	V3	1				
UpperCanada	V3					
Barkley	V4					
Gervais	V4					
Robertson	V4					
Trailer	V4	1				
Veltkamp	V4	1				
Venema	V4	1				
Wilson	V4	1				
Zeron	V4	1				
Bilmer	V4	1				
Burles	V4	1				
Dafoe	V4		1			
English	V4	1	1			
GravelPit	V4	1				
Hasson	V4	1				
Hooker	V4	1				
McIntosh	V4	1				
Pamkoski	V4	1			1	
Popoff	V4	1				
Vol	V4	1				
Brouseville	V4	1				
Corner	V4	1				
Godwin	V4	1				
Luther	V4	1				
Rooney	V4	1			1	
Rost	V4	1				
Sayean	V4	1				
Smith	V4	1?				
Wyands	V4					
Beauregard	V4	1				
Ferguson_1	V4	1				
Ferguson_2	V4	1				
McKenzie	V4	1				
Sneath	V4	1				
UpperCanada	V4		1			1
Wagemans_1	V4	1	1			
Wagemans_2	V4	1				

Bilmer	v5leopardfrogs				
Brouseville	v5leopardfrogs				
Burles	v5leopardfrogs	1			
Corner	v5leopardfrogs	1			
Dafoe	v5leopardfrogs	4			
English	v5leopardfrogs	20			
Godwin	v5leopardfrogs				
GravelPit	v5leopardfrogs				
Hasson	v5leopardfrogs	1			
Hooker	v5leopardfrogs				
Luther	v5leopardfrogs				
McIntosh	v5leopardfrogs				
Pamkoski	v5leopardfrogs				
Popoff	v5leopardfrogs				
Rooney	v5leopardfrogs	5			
Rost	v5leopardfrogs				
Sayean	v5leopardfrogs				
Smith	v5leopardfrogs	2			
Trailer	v5leopardfrogs				
Veltkamp	v5leopardfrogs				
Vol	v5leopardfrogs				
Wilson	v5leopardfrogs				
Wyands	v5leopardfrogs				
Zeron	v5leopardfrogs				
Barkley	v5leopardfrogs				
Beauregard	v5leopardfrogs				
Ferguson_1	v5leopardfrogs				
Ferguson_2	v5leopardfrogs	20			
Gervais	v5leopardfrogs				
McKenzie	v5leopardfrogs				
Robertson	v5leopardfrogs				
Sneath	v5leopardfrogs				
UpperCanada	v5leopardfrogs	7			
Venema	v5leopardfrogs				
Wagemans_1	v5leopardfrogs	5			
Wagemans_2	v5leopardfrogs				

Chapter 3 & 4 Raw data collected in 2007

NOTE: The data is arranged in several tables. 'Site' and 'Survey' are present in each table to allow the tables to be linked if required. Data are sorted first by survey, then by survey date, then by site name.

Environmental Data - 2007

Survey - 1 to 9 - night surveys

v1 to v4 - visual day survey

Note: The results of call survey 9 were not used in any analysis.

Wind - Beaufort wind scale:

0	Calm	Calm, smoke rises vertically
1	Light Air	Smoke drift indicates wind direction, still wind vanes
2	Light Breeze	Wind felt on face, leaves rustle, vanes begin to move
3	Gentle Breeze	Leaves and small twigs constantly moving, light flags extended
4	Moderate Breeze	Dust, leaves, and loose paper lifted, small tree branches move
5	Fresh Breeze	Small trees in leaf begin to sway
6	Strong Breeze	Larger tree branches moving, whistling in wires
7	Near Gale	Whole trees moving, resistance felt walking against wind
8	Gale	Whole trees in motion, resistance felt walking against wind

Cloud

0	clear
1	partly cloudy or variable
2	cloudy or overcast
3	fog
4	drizzle
5	rain

Temp - Temperature in degrees Celsius.

Pondname	Survey	Date	Start Time	Wind	Cloud	Temp
Bilmer	1	02/04/2007	22:21	1	4	6.2
Burles	1	02/04/2007	22:01	1	4	6.9
Ferguson_2	1	02/04/2007	20:48	2	2	7
GravelPit	1	02/04/2007	21:36	2	2	7.1
Hooker	1	02/04/2007	22:11	1	4	6.9
McIntosh	1	02/04/2007	21:01	2	2	7.1
McKenzie	1	02/04/2007	20:29	3	2	7.1
Popoff	1	02/04/2007	21:48	1	4	7.2
Sneath	1	02/04/2007	20:14	2	2	7.5
Vol	1	02/04/2007	21:17	2	2	7.3
Wagemans_1	1	02/04/2007	20:00	3	2	7.9
Brouseville	1	04/04/2007	20:44	2	3	2.4
Corner	1	04/04/2007	20:17	4	4	3.7

Hasson	1	04/04/2007	21:14	2	4	2.8
Luther	1	04/04/2007	20:58	3	4	2.8
Robertson	1	04/04/2007	22:27	1	2	2.4
Rooney	1	04/04/2007	19:59	2	4	3.7
Smith	1	04/04/2007	20:29	4	4	2.7
Trailer	1	04/04/2007	22:00	2	2	2.7
Veltkamp	1	04/04/2007	21:27	1	2	2.2
Venema	1	04/04/2007	22:15	1	2	3.4
Wilson	1	04/04/2007	21:44	2	2	2.6
Brouseville	2	13/04/2007	22:01	2	4	3
Corner	2	13/04/2007	22:26	3	4	3
Hasson	2	13/04/2007	21:27	1	4	4
Luther	2	13/04/2007	21:45	2	4	3
Robertson	2	13/04/2007	20:13	4	4	4
Rooney	2	13/04/2007	22:44	2	4	3
Smith	2	13/04/2007	22:14	2	4	3
Trailer	2	13/04/2007	20:41	3	4	4
Veltkamp	2	13/04/2007	21:13	1	4	4
Venema	2	13/04/2007	20:26	3	4	4
Wilson	2	13/04/2007	20:59	3	4	4
Bilmer	2	14/04/2007	20:15	0	2	4
Burles	2	14/04/2007	20:39	0	2	4
Ferguson_2	2	14/04/2007	21:49	0	2	3
GravelPit	2	14/04/2007	21:06	0	2	4
Hooker	2	14/04/2007	20:27	0	2	4
McIntosh	2	14/04/2007	21:35	0	2	3
McKenzie	2	14/04/2007	22:01	0	2	3
Popoff	2	14/04/2007	20:53	0	2	4
Sneath	2	14/04/2007	22:16	0	2	3
Vol	2	14/04/2007	21:25	0	2	3
Wagemans_1	2	14/04/2007	22:29	0	2	3
Bilmer	3	18/04/2007	21:41	1	0	7
Burles	3	18/04/2007	21:16	1	0	6
Ferguson_2	3	18/04/2007	22:49	3	0	7
GravelPit	3	18/04/2007	20:50	1	0	8
Hooker	3	18/04/2007	21:29	1	0	7
McIntosh	3	18/04/2007	23:01	3	0	8
McKenzie	3	18/04/2007	22:36	3	0	7
Popoff	3	18/04/2007	21:03	1	0	9
Sneath	3	18/04/2007	22:20	2	0	8
Vol	3	18/04/2007	20:31	0	0	7
Wagemans_1	3	18/04/2007	22:09	1	0	7
Brouseville	3	19/04/2007	22:49	0	0	4
Corner	3	19/04/2007	22:23	0	0	4
Hasson	3	19/04/2007	20:19	0	0	10
Luther	3	19/04/2007	23:03	0	0	4
Robertson	3	19/04/2007	21:36	0	0	6
Rooney	3	19/04/2007	22:05	0	0	5
Smith	3	19/04/2007	22:35	0	0	4
Trailer	3	19/04/2007	21:08	0	0	8
Veltkamp	3	19/04/2007	20:35	0	0	8
Venema	3	19/04/2007	21:24	0	0	7
Wilson	3	19/04/2007	20:49	0	0	7
Bilmer	4	22/04/2007	21:53	1	0	18
Burles	4	22/04/2007	22:20	2	0	18

Ferguson_2	4	22/04/2007	20:38	3	0	18
GravelPit	4	22/04/2007	22:44	2	0	16
Hooker	4	22/04/2007	22:06	2	0	18
McIntosh	4	22/04/2007	20:23	1	0	18
McKenzie	4	22/04/2007	20:51	3	0	18
Popoff	4	22/04/2007	22:34	3	0	18
Sneath	4	22/04/2007	21:07	2	0	18
Vol	4	22/04/2007	23:04	1	0	16
Wagemans_1	4	22/04/2007	21:20	3	0	18
Brouseville	4	23/04/2007	20:40	1	2	14
Corner	4	23/04/2007	21:07	3	2	13
Hasson	4	23/04/2007	23:07	1	1	14
Luther	4	23/04/2007	20:25	3	2	15
Robertson	4	23/04/2007	21:53	4	3	14
Rooney	4	23/04/2007	21:26	0	1	14
Smith	4	23/04/2007	20:51	4.5	2	14
Trailer	4	23/04/2007	22:21	2	3	14
Veltkamp	4	23/04/2007	22:50	1	1	14
Venema	4	23/04/2007	22:07	2	3	14
Wilson	4	23/04/2007	22:37	2	1	14
Bilmer	5	29/04/2007	22:56	1	2	13
Burles	5	29/04/2007	22:33	2	2	13
Ferguson_2	5	29/04/2007	21:23	1	1	12
GravelPit	5	29/04/2007	22:07	1	1	12
Hooker	5	29/04/2007	22:45	1	2	12
McIntosh	5	29/04/2007	21:36	1	1	11
McKenzie	5	29/04/2007	21:10	1	1	13
Popoff	5	29/04/2007	22:19	2	2	13
Sneath	5	29/04/2007	20:53	1	1	12
Vol	5	29/04/2007	21:49	1	1	12
Wagemans_1	5	29/04/2007	20:34	1	1	14
Brouseville	5	01/05/2007	21:25	0	2	11
Corner	5	01/05/2007	20:54	0	2	11
Hasson	5	01/05/2007	21:59	0	1	9
Luther	5	01/05/2007	21:40	0	2	9
Robertson	5	01/05/2007	23:15	1	1	9
Rooney	5	01/05/2007	20:35	0	1	12
Smith	5	01/05/2007	21:09	0	1	11
Trailer	5	01/05/2007	22:45	1	1	10
Veltkamp	5	01/05/2007	22:14	0	1	10
Venema	5	01/05/2007	23:02	1	1	9
Wilson	5	01/05/2007	22:29	1	1	9
Brouseville	6	08/05/2007	22:29	0	0	15.4
Corner	6	08/05/2007	22:56	1	0	16.9
Hasson	6	08/05/2007	21:57	1	0	18.3
Luther	6	08/05/2007	22:15	0	0	18
Robertson	6	08/05/2007	20:43	3	1	20
Rooney	6	08/05/2007	23:15	1	0	15.4
Smith	6	08/05/2007	22:44	1	0	16
Trailer	6	08/05/2007	21:10	1	0	19
Veltkamp	6	08/05/2007	21:45	1	0	18.1
Venema	6	08/05/2007	20:55	2	0	19
Wilson	6	08/05/2007	21:25	2	0	18.5
Bilmer	6	09/05/2007	20:44	0	2	20
Burles	6	09/05/2007	21:08	0	2	17

Ferguson_2	6	09/05/2007	22:26	0	1	15
GravelPit	6	09/05/2007	21:36	0	2	17.4
Hooker	6	09/05/2007	20:56	0	2	17
McIntosh	6	09/05/2007	22:08	0	0	16
McKenzie	6	09/05/2007	22:34	0	0	16
Popoff	6	09/05/2007	21:23	0	2	16.8
Sneath	6	09/05/2007	22:49	0	0	15
Vol	6	09/05/2007	21:56	0	2	15
Wagemans_1	6	09/05/2007	23:02	0	0	15
Bilmer	7	24/05/2007	22:13	0	0	23
Burles	7	24/05/2007	21:49	1	0	23
Ferguson_2	7	24/05/2007	23:26	2	0	22
GravelPit	7	24/05/2007	21:23	0	0	24
Hooker	7	24/05/2007	22:02	0	0	23
McIntosh	7	24/05/2007	23:46	0	0	21
McKenzie	7	24/05/2007	23:13	2	0	22
Popoff	7	24/05/2007	21:35	1	0	24
Sneath	7	24/05/2007	22:58	1	0	22
Vol	7	24/05/2007	21:05	0	0	25
Wagemans_1	7	24/05/2007	22:45	2	0	22
Brouseville	7	25/05/2007	23:49	1	1	20
Corner	7	25/05/2007	23:14	1	0	18
Hasson	7	25/05/2007	21:03	1	1	21
Luther	7	25/05/2007	23:56	0	0	19
Robertson	7	25/05/2007	22:23	1	0	20
Rooney	7	25/05/2007	22:53	0	0	20
Smith	7	25/05/2007	23:27	1	0	19
Trailer	7	25/05/2007	21:51	1	0	21
Veltkamp	7	25/05/2007	21:19	0	0	21
Venema	7	25/05/2007	22:09	1	1	20
Wilson	7	25/05/2007	21:35	1	0	21
Brouseville	8	11/06/2007	21:35	0	0	18.9
Corner	8	11/06/2007	22:01	0	0	19.3
Hasson	8	11/06/2007	00:09	0	0	18.1
Luther	8	11/06/2007	21:18	0	1	20.3
Robertson	8	11/06/2007	22:57	0	0	19.3
Rooney	8	11/06/2007	22:24	0	0	19.4
Smith	8	11/06/2007	21:48	0	0	19.7
Trailer	8	11/06/2007	23:26	0	0	18.3
Veltkamp	8	11/06/2007	23:56	0	0	19.2
Venema	8	11/06/2007	23:11	0	0	19
Wilson	8	11/06/2007	23:42	0	0	18.3
Bilmer	8	12/06/2007	22:48	0	1	21
Burles	8	12/06/2007	23:15	0	1	21
Ferguson_2	8	12/06/2007	21:37	0	0	20
GravelPit	8	12/06/2007	23:39	1	4	21
Hooker	8	12/06/2007	23:01	0	1	21
McIntosh	8	12/06/2007	21:19	0	0	20
McKenzie	8	12/06/2007	21:51	0	0	20
Popoff	8	12/06/2007	23:26	0	4	21
Sneath	8	12/06/2007	22:04	0	0	20
Vol	8	12/06/2007	23:57	0	4	22
Wagemans_1	8	12/06/2007	22:18	0	1	20
Corner	9	30/07/2007	21:21	1	0	20
Hasson	9	30/07/2007	22:19	0	0	20

Luther	9	30/07/2007	22:01	0	0	19
Robertson	9	30/07/2007	23:34	0	0	20
Rooney	9	30/07/2007	21:03	0	0	22
Smith	9	30/07/2007	21:34	0	0	21
Trailer	9	30/07/2007	23:04	0	0	21
Veltkamp	9	30/07/2007	22:31	0	0	20
Venema	9	30/07/2007	23:21	0	0	20
Wilson	9	30/07/2007	22:48	0	0	21
Bilmer	9	31/07/2007	23:16	0	1	19
Burles	9	31/07/2007	22:50	0	1	19
Ferguson_2	9	31/07/2007	21:45	0	1	20
GravelPit	9	31/07/2007	22:29	0	1	20
Hooker	9	31/07/2007	23:05	0	1	19
McIntosh	9	31/07/2007	21:59	0	1	20
McKenzie	9	31/07/2007	21:32	0	0	20
Popoff	9	31/07/2007	22:40	0	1	19
Sneath	9	31/07/2007	21:15	0	0	22
Vol	9	31/07/2007	22:11	0	1	20
Wagemans_1	9	31/07/2007	20:59	0	0	22
Brouseville	9	31/07/2007	Not recorded pond dried up			
Brouseville	v1	03/05/2007	14:03	1	0	16
Corner	v1	03/05/2007	13:20	4	0	16
Hasson	v1	03/05/2007	15:16	1	0	17
Luther	v1	03/05/2007	14:19	1	0	17.5
Rooney	v1	03/05/2007	10:32	1	0	15
Smith	v1	03/05/2007	13:35	1	0	16
Veltkamp	v1	03/05/2007	15:43	1	0	17
Wilson	v1	03/05/2007	16:18	2	0	17
Ferguson_2	v1	04/05/2007	15:53	2	0	19
McKenzie	v1	04/05/2007	14:53	1	0	18
Robertson	v1	04/05/2007	12:12	2	0	18
Sneath	v1	04/05/2007	14:26	2.5	0	18
Trailer	v1	04/05/2007	10:51	2	0	19
Venema	v1	04/05/2007	11:54	2	0	17
Wagemans_1	v1	04/05/2007	13:35	3.5	0	18
Bilmer	v1	05/05/2007	13:43	2	0	16
Burles	v1	05/05/2007	13:09	2	0	16
GravelPit	v1	05/05/2007	12:33	2	0	15
Hooker	v1	05/05/2007	13:24	2	0	16
McIntosh	v1	05/05/2007	11:27	2	0	15
Popoff	v1	05/05/2007	12:50	2	0	16
Vol	v1	05/05/2007	12:15	2	0	15
Bilmer	v2	22/05/2007	12:13	1	0	19
Burles	v2	22/05/2007	13:01	1	0	21
Ferguson_2	v2	22/05/2007	15:17	1	0	22
GravelPit	v2	22/05/2007	13:39	1	0	21
Hooker	v2	22/05/2007	12:37	1	0	20
McIntosh	v2	22/05/2007	14:21	1	0	21
Popoff	v2	22/05/2007	13:20	1	0	21
Vol	v2	22/05/2007	14:04	1	0	21
Hasson	v2	23/05/2007	16:20	1	0	28
McKenzie	v2	23/05/2007	10:16	1	0	20
Robertson	v2	23/05/2007	12:29	1	0	24
Sneath	v2	23/05/2007	11:10	1	0	21

Trailer	v2	23/05/2007	14:14	1	0	27
Veltkamp	v2	23/05/2007	15:49	1	0	28
Venema	v2	23/05/2007	13:57	1	0	26
Wagemans_1	v2	23/05/2007	11:31	1	0	22
Wilson	v2	23/05/2007	15:22	1	0	27
Brouseville	v2	24/05/2007	11:21	1	0	27
Corner	v2	24/05/2007	11:58	2	0	27
Luther	v2	24/05/2007	10:36	1	0	25
Rooney	v2	24/05/2007	12:45	1	0	29
Smith	v2	24/05/2007	11:32	2	0	26
Brouseville	v3	13/06/2007	15:31	3	0	27
Corner	v3	13/06/2007	14:52	3	0	27
Hasson	v3	13/06/2007	16:28	3	0	25
Luther	v3	13/06/2007	15:40	2	0	26
Rooney	v3	13/06/2007	11:46	2.5	0	26
Smith	v3	13/06/2007	15:06	3	0	27
McKenzie	v3	14/06/2007	15:23	2	1	25
Robertson	v3	14/06/2007	12:39	1	1	25
Sneath	v3	14/06/2007	14:55	2	1	25
Trailer	v3	14/06/2007	11:12	1	1	21
Veltkamp	v3	14/06/2007	10:19	1	0	21
Venema	v3	14/06/2007	12:20	1	1	21
Wagemans_1	v3	14/06/2007	14:07	2	1	25
Wilson	v3	14/06/2007	10:47	1	0	21
Bilmer	v3	15/06/2007	14:10	1	0	27
Burles	v3	15/06/2007	13:34	1	0	27
Ferguson_2	v3	15/06/2007	10:26	1	0	25
GravelPit	v3	15/06/2007	12:03	1	0	26.4
Hooker	v3	15/06/2007	13:54	1	0	27
McIntosh	v3	15/06/2007	11:04	1	0	24
Popoff	v3	15/06/2007	12:22	1	0	26
Vol	v3	15/06/2007	11:42	1	0	24
Bilmer	v4	26/06/2007	12:10	1.5	0	30.5
Burles	v4	26/06/2007	13:08	2	0	28.1
Ferguson_2	v4	26/06/2007	16:16	2.5	0	29.2
GravelPit	v4	26/06/2007	13:55	2	0	30.4
Hooker	v4	26/06/2007	12:40	2	0	31.5
McIntosh	v4	26/06/2007	15:43	1.5	0	32
Popoff	v4	26/06/2007	13:35	2	0	32
Vol	v4	26/06/2007	14:25	2	0	30.9
McKenzie	v4	27/06/2007	10:47	1	0	30
Robertson	v4	27/06/2007	12:59	3	0	30
Sneath	v4	27/06/2007	11:44	1	1	30
Trailer	v4	27/06/2007	14:29	3.5	1	31.2
Venema	v4	27/06/2007	14:11	2	1	31.2
Wagemans_1	v4	27/06/2007	12:09	2	1	30
Wilson	v4	27/06/2007	15:34	4.5	1	30.7
Corner	v4	28/06/2007	12:36	3.5	0	24.2
Hasson	v4	28/06/2007	10:56	2	1	21.4
Luther	v4	28/06/2007	11:19	2	1	24.1
Rooney	v4	28/06/2007	13:38	2.5	1	26.8
Smith	v4	28/06/2007	12:03	3	0	24.6
Veltkamp	v4	28/06/2007	10:33	2	1	22.8
Brouseville	v4	28/06/2007	Not recorded pond dried up			

2007 Field Data Chapters 3 & 4 - Call Surveys - Calling at pond

NOTE: Survey 9 was not used in the analysis

Species are: Species: WDF = Wood frog, WCF = Western chorus frog; SPP = Spring peeper; NLF = Northern leopard frog; AMT = American toad; GTF = Gray treefrog; GRF = Green frog; MIF = Mink frog; BUF = Bull frog.

Calling activity for each species

- 0** no individuals calling
- 1** individual(s) can be counted, calls are not overlapping
- 2** calls of <15 individuals can be distinguished, but there is some overlapping
- 3** calls of ≥ 15 individuals

Pondname	Survey	WDF	WCF	SPP	AMT	NLF	GTF	GRF	BUF
Bilmer	1	1							
Burles	1								
Ferguson_2	1								
GravelPit	1								
Hooker	1								
McIntosh	1		2	1					
McKenzie	1								
Popoff	1								
Sneath	1								
Vol	1								
Wagemans_1	1								
Brouseville	1								
Corner	1								
Hasson	1								
Luther	1	3	1	3					
Robertson	1								
Rooney	1								
Smith	1								
Trailer	1								
Veltkamp	1	1		1					
Venema	1								
Wilson	1								
Brouseville	2								
Corner	2								
Hasson	2								
Luther	2	3	1	2					
Robertson	2								
Rooney	2								
Smith	2								
Trailer	2								
Veltkamp	2	1		2					
Venema	2								
Wilson	2								
Bilmer	2			1					
Burles	2								
Ferguson_2	2								

GravelPit	2								
Hooker	2								
McIntosh	2	3	3						
McKenzie	2								
Popoff	2								
Sneath	2								
Vol	2								
Wagemans_1	2								
Bilmer	3	2		1					
Burles	3								
Ferguson_2	3								
GravelPit	3								
Hooker	3								
McIntosh	3	3	2	1					
McKenzie	3								
Popoff	3								
Sneath	3								
Vol	3								
Wagemans_1	3								
Brouseville	3			1					
Corner	3								
Hasson	3								
Luther	3	2		3		1			
Robertson	3								
Rooney	3								
Smith	3								
Trailer	3								
Veltkamp	3	3		3					
Venema	3								
Wilson	3								
Bilmer	4	2		3					
Burles	4			2					
Ferguson_2	4								
GravelPit	4								
Hooker	4					1			
McIntosh	4	2	1	3		1			
McKenzie	4								
Popoff	4					1			
Sneath	4			1					
Vol	4								
Wagemans_1	4								
Brouseville	4			1					
Corner	4								
Hasson	4			2	1				
Luther	4			3		2			
Robertson	4								
Rooney	4			1					
Smith	4			1					
Trailer	4								
Veltkamp	4	2		3		1			
Venema	4								
Wilson	4			1	1				
Bilmer	5			2					
Burles	5			2	2				
Ferguson_2	5								

GravelPit	5			2					
Hooker	5								
McIntosh	5		1	3					
McKenzie	5								
Popoff	5								
Sneath	5			1					
Vol	5		1	1					
Wagemans_1	5								
Brouseville	5			1					
Corner	5								
Hasson	5			2	1	1			
Luther	5			2	1	1			
Robertson	5								
Rooney	5								
Smith	5			1					
Trailer	5			1					
Veltkamp	5			2	1	1			
Venema	5								
Wilson	5								
Brouseville	6			1	1				
Corner	6								
Hasson	6			1	2				
Luther	6		1	3					
Robertson	6								
Rooney	6			1					
Smith	6			1					
Trailer	6								
Veltkamp	6			2	1	1			
Venema	6								
Wilson	6				1				
Bilmer	6			3	1				
Burles	6			3	1				
Ferguson_2	6				1				
GravelPit	6			1	1				
Hooker	6			1					
McIntosh	6			3	2	1			
McKenzie	6								
Popoff	6				2				
Sneath	6				1				
Vol	6								
Wagemans_1	6								
Bilmer	7			1	1		2		
Burles	7			1			2		
Ferguson_2	7								
GravelPit	7				1				
Hooker	7								
McIntosh	7						3	1	
McKenzie	7							1	1
Popoff	7								
Sneath	7								
Vol	7						1		
Wagemans_1	7								
Brouseville	7								
Corner	7								
Hasson	7			1			1		

Luther	7			1			2	1	
Robertson	7								
Rooney	7								1
Smith	7								
Trailer	7								
Veltkamp	7			1			3		
Venema	7						2		
Wilson	7				2				
Brouseville	8				1		2		
Corner	8						1		
Hasson	8							1	
Luther	8						2	1	
Robertson	8								
Rooney	8							1	
Smith	8						1		
Trailer	8							2	
Veltkamp	8						1	1	
Venema	8						2		
Wilson	8							1	
Bilmer	8						1	1	
Burles	8						1	2	
Ferguson_2	8							1	
GravelPit	8							1	
Hooker	8						1	1	
McIntosh	8						2	2	
McKenzie	8						1	1	
Popoff	8							1	
Sneath	8							1	
Vol	8								
Wagemans_1	8							2	
Corner	9							1	
Hasson	9							1	
Luther	9								
Robertson	9								
Rooney	9							1	1
Smith	9								1
Trailer	9							2	
Veltkamp	9								
Venema	9							1	
Wilson	9								
Bilmer	9								
Burles	9							1	
Ferguson_2	9								
GravelPit	9								
Hooker	9							1	
McIntosh	9							1	
McKenzie	9								
Popoff	9							1	
Sneath	9							1	
Vol	9								
Wagemans_1	9							1	
Brouseville	9								

2007 Field Data Chapters 3 & 4 - Call Surveys - Calling within 100 m of pond edge

NOTE: Survey 9 was not used in the analysis

Species are: Species: WDF = Wood frog, WCF = Western chorus frog; SPP = Spring peeper; NLF = Northern leopard frog; AMT = American toad; GTF = Gray treefrog; GRF = Green frog; MIF = Mink frog; BUF = Bull frog.

Calling activity for each species

- 0** no individuals calling
- 1** individual(s) can be counted, calls are not overlapping
- 2** calls of <15 individuals can be distinguished, but there is some overlapping
- 3** calls of ≥ 15 individuals

Pondname	Survey	WDF	WCF	SPP	AMT	NLF	GTF	GRF	BUF
Bilmer	1								
Burles	1								
Ferguson_2	1								
GravelPit	1								
Hooker	1								
McIntosh	1								
McKenzie	1			1					
Popoff	1								
Sneath	1		1						
Vol	1		1						
Wagemans_1	1								
Brouseville	1								
Corner	1								
Hasson	1								
Luther	1								
Robertson	1								
Rooney	1								
Smith	1								
Trailer	1								
Veltkamp	1								
Venema	1								
Wilson	1								
Brouseville	2								
Corner	2								
Hasson	2		1						
Luther	2								
Robertson	2								
Rooney	2								
Smith	2			1					
Trailer	2								
Veltkamp	2								
Venema	2								
Wilson	2								
Bilmer	2	1							
Burles	2								
Ferguson_2	2								

GravelPit	2								
Hooker	2								
McIntosh	2								
McKenzie	2			2					
Popoff	2								
Sneath	2								
Vol	2		1						
Wagemans_1	2								
Bilmer	3								
Burles	3	1		1					
Ferguson_2	3								
GravelPit	3								
Hooker	3								
McIntosh	3								
McKenzie	3			2					
Popoff	3								
Sneath	3	2	2						
Vol	3								
Wagemans_1	3								
Brouseville	3								
Corner	3	1							
Hasson	3	3	1	2					
Luther	3								
Robertson	3								
Rooney	3			1					
Smith	3	1		1					
Trailer	3								
Veltkamp	3								
Venema	3								
Wilson	3								
Bilmer	4								
Burles	4								
Ferguson_2	4								
GravelPit	4		1						
Hooker	4								
McIntosh	4								
McKenzie	4	1		3					
Popoff	4								
Sneath	4								
Vol	4		1						
Wagemans_1	4			2					
Brouseville	4								
Corner	4			1	2				
Hasson	4	1				1			
Luther	4								
Robertson	4								
Rooney	4								
Smith	4								
Trailer	4								
Veltkamp	4								
Venema	4								
Wilson	4								
Bilmer	5				1				
Burles	5								
Ferguson_2	5								

GravelPit	5								
Hooker	5								
McIntosh	5								
McKenzie	5			3					
Popoff	5								
Sneath	5								
Vol	5								
Wagemans_1	5								
Brouseville	5								
Corner	5			1	1				
Hasson	5								
Luther	5								
Robertson	5								
Rooney	5			1					
Smith	5				1	1			
Trailer	5								
Veltkamp	5								
Venema	5		1						
Wilson	5								
Brouseville	6								
Corner	6			1	1				
Hasson	6								
Luther	6				1				
Robertson	6								
Rooney	6								
Smith	6								
Trailer	6			1					
Veltkamp	6								
Venema	6			1	1				
Wilson	6								
Bilmer	6								
Burles	6				2				
Ferguson_2	6								
GravelPit	6				1				
Hooker	6								
McIntosh	6								
McKenzie	6			2					
Popoff	6								
Sneath	6			1					
Vol	6			1	1				
Wagemans_1	6			1	1				
Bilmer	7								
Burles	7				1				
Ferguson_2	7								
GravelPit	7						1		
Hooker	7								
McIntosh	7								
McKenzie	7						1		
Popoff	7								
Sneath	7								
Vol	7			1	1				
Wagemans_1	7				1				
Brouseville	7								
Corner	7								
Hasson	7								

Luther	7								
Robertson	7								
Rooney	7								
Smith	7								
Trailer	7								
Veltkamp	7								
Venema	7								
Wilson	7								
Brouseville	8								
Corner	8								
Hasson	8								
Luther	8								
Robertson	8								
Rooney	8						1		
Smith	8								
Trailer	8								
Veltkamp	8								
Venema	8								
Wilson	8								
Bilmer	8								
Burles	8								
Ferguson_2	8								
GravelPit	8						1		
Hooker	8								
McIntosh	8								
McKenzie	8								
Popoff	8								
Sneath	8								
Vol	8								
Wagemans_1	8								
Corner	9								
Hasson	9								
Luther	9								
Robertson	9								
Rooney	9								
Smith	9								
Trailer	9								
Veltkamp	9								
Venema	9								
Wilson	9								
Bilmer	9								
Burles	9								
Ferguson_2	9								
GravelPit	9								
Hooker	9								
McIntosh	9								
McKenzie	9								
Popoff	9								
Sneath	9								
Vol	9								
Wagemans_1	9								
Brouseville	9								

2007 Field Data Chapters 3 & 4 - Visual Surveys - Number of adult frogs

Species are: Species: WDF = Wood frog, WCF = Western chorus frog; SPP = Spring peeper; NLF = Northern leopard frog; AMT = American toad; GTF = Gray treefrog; GRF = Green frog; MIF = Mink frog; BUF = Bull frog.

Pondname	Survey	Time taken for visual survey (minutes)	WDF	WCF	SPP	AMT	NLF	GTF	GRF	BUF	MIF
Brouseville	v1	4					3		1		
Corner	v1	4					3				
Hasson	v1	15				1	1				
Luther	v1	45									
Rooney	v1	132					6		20	1	7
Smith	v1	15					7		12	3	1
Veltkamp	v1	25									
Wilson	v1	23							2		
Ferguson_2	v1	23					3				
McKenzie	v1	45					1		2		
Robertson	v1	27					1				
Sneath	v1	12									
Trailer	v1	53							1		
Venema	v1	7									
Wagemans_1	v1	40					1				
Bilmer	v1	12									
Burles	v1	8					4				
GravelPit	v1	10									
Hooker	v1	11					1		6		
McIntosh	v1	38					1		10		
Popoff	v1	7							3		
Vol	v1	5					1				
Bilmer	v2	14							2		
Burles	v2	9									
Ferguson_2	v2	22							1		
GravelPit	v2	11							1		
Hooker	v2	17							28		
McIntosh	v2	45					6		45		
Popoff	v2	11					5		6	1	
Vol	v2	8							2		
Hasson	v2	8					1				
McKenzie	v2	42							6		
Robertson	v2	21					1		2		
Sneath	v2	12					1		1		
Trailer	v2	58					1		24		
Veltkamp	v2	22	1				6		22		
Venema	v2	7									
Wagemans_1	v2	39					5		6		
Wilson	v2	17									
Brouseville	v2	3					1				
Corner	v2	4					1				
Luther	v2	33				1	3		3		
Rooney	v2	107					6		31	1	6

Smith	v2	19				2	18		26	2	
Brouseville	v3	3							1		
Corner	v3	6							3		
Hasson	v3	10							1		
Luther	v3	36							0		
Rooney	v3	118					1		33	1	1
Smith	v3	15							11		
McKenzie	v3	47							10	1	
Robertson	v3	21							0		
Sneath	v3	16							11		
Trailer	v3	56							17		
Veltkamp	v3	20							6		
Venema	v3	8							8		
Wagemans_1	v3	38					3		6		
Wilson	v3	17							3		
Bilmer	v3	10							15		
Burles	v3	11					1		24		
Ferguson_2	v3	26							3		
GravelPit	v3	9							1		
Hooker	v3	9							14		
McIntosh	v3	28							19		1
Popoff	v3	7							8		
Vol	v3	7							3		
Bilmer	v4	17							20		
Burles	v4	14							14		
Ferguson_2	v4	23							3		
GravelPit	v4	17							3		
Hooker	v4	15							23		
McIntosh	v4	21							13		
Popoff	v4	12							26		
Vol	v4	13							14		
McKenzie	v4	40							16		
Robertson	v4	13							1		
Sneath	v4	15							29		
Trailer	v4	54							9		
Venema	v4	7							15		
Wagemans_1	v4	29							7		
Wilson	v4	19							12		
Corner	v4	9							18		
Hasson	v4	9							1		
Luther	v4	16							0		
Rooney	v4	116					3		95	3	5
Smith	v4	13					3		28		
Veltkamp	v4	12							20		
Brouseville	v4	SURVEY NOT DONE - POND DRIED UP!!!							0		

2007 Field Data Chapters 3 & 4 - Visual Surveys - Presence (1) of young of year frogs

NOTE: This data was only used in species richness calculations (i.e. species richness = sum of all presences (calling + adults in visual surveys + young frogs + young of year frogs))

Species are: Species: WDF = Wood frog, WCF = Western chorus frog; SPP = Spring peeper; NLF = Northern leopard frog; AMT = American toad; GTF = Gray treefrog; GRF = Green frog; MIF = Mink frog; BUF = Bull frog.

Pondname	Survey	WDF	NLF	GRF	MIF
Brouseville	v1				
Corner	v1				
Hasson	v1				
Luther	v1				
Rooney	v1				1
Smith	v1			1	
Veltkamp	v1			1	
Wilson	v1				
Ferguson_2	v1				
McKenzie	v1			1	
Robertson	v1				
Sneath	v1		1		
Trailer	v1				
Venema	v1				
Wagemans_1	v1			1	
Bilmer	v1				
Burles	v1				
GravelPit	v1				
Hooker	v1				
McIntosh	v1				
Popoff	v1				
Vol	v1				
Bilmer	v2			1	
Burles	v2				
Ferguson_2	v2				
GravelPit	v2				
Hooker	v2			1	
McIntosh	v2				
Popoff	v2				
Vol	v2				
Hasson	v2				
McKenzie	v2				
Robertson	v2				
Sneath	v2				
Trailer	v2			1	
Veltkamp	v2				
Venema	v2				
Wagemans_1	v2		1	1	
Wilson	v2				
Brouseville	v2				
Corner	v2				

Luther	v2	1			
Rooney	v2			1	1
Smith	v2			1	
Brouseville	v3				
Corner	v3				
Hasson	v3			1	
Luther	v3				
Rooney	v3			1	
Smith	v3			1	
McKenzie	v3			1	1
Robertson	v3			1	
Sneath	v3			1	
Trailer	v3			1	
Veltkamp	v3				
Venema	v3				
Wagemans_1	v3				
Wilson	v3				
Bilmer	v3				
Burles	v3			1	
Ferguson_2	v3			1	
GravelPit	v3			1	
Hooker	v3				
McIntosh	v3				
Popoff	v3			1	
Vol	v3			1	
Bilmer	v4			1	
Burles	v4			1	
Ferguson_2	v4			1	
GravelPit	v4			1	
Hooker	v4			1	
McIntosh	v4			1	
Popoff	v4				
Vol	v4			1	
McKenzie	v4			1	
Robertson	v4			1	
Sneath	v4			1	
Trailer	v4			1	
Venema	v4				
Wagemans_1	v4			1	
Wilson	v4			1	
Corner	v4			1	
Hasson	v4				
Luther	v4				
Rooney	v4			1	1
Smith	v4				
Veltkamp	v4			1	
Brouseville	v4				