

Post-fledging Ecology of Two Songbird Species  
Across a Rural-to-Urban Landscape Gradient

Thesis

Presented in Partial Fulfillment of the Requirements for the Degree Master of Science  
in the Graduate School of The Ohio State University

By

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## Abstract

Urbanization alters the composition and structure of bird communities, yet little is known about the demographic processes underlying these patterns. Among the well-described urban ecological phenomena that could affect avian demography are increased abundances of generalist predators and invasive exotic shrubs. Such urban-associated changes should have particularly strong demographic consequences during the post-fledging stage of the avian life cycle, when juvenile birds have limited flight capabilities, are dependent upon parents for resource acquisition, and are vulnerable to predation. While ecologists have assumed that survival rates of fledgling birds are depressed in urban landscapes, few studies have tested this assumption. To understand how urbanization influences the ecology of post-fledging birds, I asked four broad questions: 1) How does fledgling survivorship vary across an urban-to-rural landscape gradient? 2) To what extent is variation in survivorship explained by fledgling age, energetic condition at time of fledging, and habitat selection? 3) How does the presence of Amur Honeysuckle (*Lonicera maackii*), an abundant exotic shrub, influence fledgling survivorship and habitat selection? and 4) Which ecological factors explain variation in natal home range extent and post-fledging dispersal timing for fledgling songbirds within an urbanizing landscape? From April - August 2008 and 2009 I used radio telemetry

technology to track the fate and movements of fledgling Northern Cardinals (*Cardinalis cardinalis*) ( $n = 45$ ) and Acadian Flycatchers (*Empidonax virescens*) ( $n = 31$ ) living in a network of riparian forests distributed along a rural-to-urban landscape gradient in central Ohio, USA. The two species respond differently to urbanization; cardinals are “urban adapters” because they become more abundant in urban forests, and flycatchers are “urban avoiders” because they become less abundant as landscapes urbanize. Like other studies, I found that predation was the primary cause of mortality of post-fledging birds, and survivorship was lowest during the first few days after fledging. Curiously, cumulative survivorship ( $\pm$  SE) of the urban avoider flycatcher was higher ( $0.720 \pm 0.097$ ; 22 days) than that of the urban adaptor cardinal ( $0.440 \pm 0.077$ ; 71 days). Across the entire post-fledging period, survivorship was not influenced by urbanization for either species. However, during the initial three days post-fledging when mortality was highest, survivorship of cardinals was promoted by an urbanizing landscape matrix. Cardinals and, to a lesser extent, flycatchers selected microhabitats that were more structurally complex than those at random plots or nest sites. In particular, cardinal fledglings selected areas rich with honeysuckle and saplings. While survival was not associated with cover by honeysuckle specifically, survivorship of both species improved with increasing structural complexity of the understory and midstory forest strata. Habitat structure also seemed to influence natal home range size ( $\pm$  SE) in Acadian Flycatchers ( $1.91 \pm 0.24$  ha), which had larger ranges in areas with more honeysuckle cover, saplings and mature trees. In contrast, variation in cardinal natal home range size ( $0.93 \pm 0.13$ ) was not well explained by a suite of physiological, social and habitat variables. Timing of dispersal of cardinals ( $46 \pm 2$  days) was best explained by and positively related to territory density of

conspecifics.

Collectively, my results indicate that a variety of ecological factors influence the survivorship and movements of fledglings in urban landscapes. Predation and habitat selection play important roles in regulating fledgling survivorship, especially during the first few days out of the nest. Habitat structure also appears to partially explain variation in home range size for flycatchers. The fact that urbanization did not negatively influence fledgling survivorship suggests that in spite of abundant predator communities, urban forests may be capable of providing suitable habitat to juvenile birds. In a rapidly urbanizing world, land use planners should strongly consider the role urban forests play in sustaining bird populations when identifying conservation priorities.

## Dedication

To my parents (James and Joanne)  
and my aunt and uncle (Ellen and Robert),  
whose collective influence made it inevitable  
that I would one day be writing about something  
of a biological nature.

## Acknowledgments

I would like to first thank Amanda Rodewald for taking me on as a Masters student. I recall her mentioning two years ago that she hoped this process would be a life changing experience. It has been in many ways, much of which is due to the mentoring, experiences, and friendship she has provided. I am extremely grateful for all. I thank my committee members, Stan Gehrt and Mazeika Sullivan, who provided thoughtful, constructive criticism throughout the process. I would also like to thank Paul Rodewald for his friendship and many impromptu conversations about birds, teaching, and life in general, and Steve Matthews and Andrew Vitz for help with analyses. Working within the Rodewald Labs has been a great pleasure, mainly for the amicable company shared by all inside and outside of work.

I extend a hearty thanks to my partner in crime, Laura Kearns, for her advice, friendship and tireless managerial skills during fieldwork. The graduate students within SENR provided much help of the academic and distinctively non-academic sorts. Many thanks to Gabriel Colorado, Erin Cashion, Ben Kahler, Dave Slager, Lauren MacDade, Courtney Quirin, Andrew Kniowski, Ajay Singh, Karen Willard, Desiree Narango, Rachel Schultz, and Katie Martin for inspiring much laughter amongst the workload. Special thanks to Ryan Zajack for the bonfires and excuses to leave the city and Felicity Newell for her company and positive reinforcement during the final months of writing. I

would also like to thank Andrew Vitz and Marja Bakermans for opening their home when I first moved to Columbus and for imparting a good deal of wisdom about birds, fieldwork, and being a graduate student in general.

I would not be writing this if it were not for the dedicated efforts in the field of many graduate students, technicians and volunteers: Angela Petersen, Christine Austin, Elizabeth Ames, Todd Jones, Liz Rogers, Jon Felix, John Fields, Bryce Adams, Chris Grimm, Sarah Rose, Kapil Mandrekar, Clayton Bell, Ryan Zajack, Erica Szeller, Kendra Carter, Jennifer Dugovich, Steven Farley, Laura Kearns, Dan Shustack, and Sarah Lehnen. I thank them all. Special thanks to Matt Kneitel who voluntarily surveyed many vegetation plots and entered copious amounts of data pro bono.

I am grateful to the National Science Foundation, Ohio Division of Wildlife, Kirtland Bird Club Ohio Avian Project Initiative, and Wilson Ornithological Society for funding this project, and to Bob Gates and the Terrestrial Wildlife Ecology Lab for providing logistical support. Dennis Hull, in particular, was invaluable in troubleshooting many field logistics. Columbus Parks and Recreation, Franklin County Metro Parks, The Nature Conservancy, Seal of Ohio (Girl Scouts), and many private landowners provided access to study sites. This research was conducted under Master Bander permit #22272 held by Paul Rodewald.

Finally, I would like to thank my undergraduate advisor, Steve Trombulak, who first put a bird in my hand some eight years ago at the Otter Creek Banding Station in Vermont, and to my family whose love, encouragement, and curiosity have contributed



hugely to the person I am today. This thesis is for them.

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## CHAPTER 1

### INTRODUCTION

The process of urbanization plays a major role in fragmenting habitat and is expected to intensify as human populations continue to concentrate in cities. Between 2003 and 2005, the global proportion of humans living in urban area increased annually by 2.1%, and by 2030, over 60% of the world's population is projected to live in urban areas (United Nations 2003). Not surprisingly, anthropogenic habitat alteration and fragmentation due to urban development is considered a serious threat to the functioning of natural ecosystems (Lindenmayer and Fischer 2006).

How an urbanizing world impacts native wildlife populations is a question of concern for ecologists, and a substantial literature has emerged (see Marzluff et al. 2008). As development alters landscapes through habitat loss and fragmentation (Brooks et al. 2002, Hoekstra et al. 2005), edge effects (Harper et al. 2005), and isolation (Lada et al. 2008), the viability of native wildlife populations may be compromised. Our understanding of these effects is probably best for birds, which have been a common

focus of urban ecological studies given their ease of study, sensitivity to environmental change (Youth 2003), and conservation concern (Rich et al. 2004). Although a few studies report that avian species richness peaks in moderately disturbed landscapes (e.g., suburbia; Blair 1996, Cam et al. 2000, Clergeau et al. 2006a), urban areas generally have lower species richness, higher avian biomass, and greater numbers of exotic species than less developed areas (Beissinger and Osborne 1982, Crooks 2004, Emlen 1974, Clergeau et al. 2006b and Mills et al 1989). Likewise, urban systems host granivorous and omnivorous guilds, whereas insectivorous species and other habitat specialists are more abundant in rural landscapes (Beissinger and Osborne 1982, Leston and Rodewald 2006, Bakermans and Rodewald 2006, Rodewald and Bakermans 2006, see Chace and Walsh 2001). Hence, as species compositions shift towards synanthropic species, avian communities in urban landscapes become more homogenized (McKinney and Lockwood 1999).

Although ecologists have a good understanding of how avian communities are structured in cities, little is known about demographic processes that operate in urbanizing landscapes (Shochat et al. 2006, Chiron and Julliard 2007, Rodewald and Shustack 2008a, Rodewald and Shustack 2008b). Ecologists have suspected that demography of urban bird populations is strongly influenced by changes in local ecological factors, including predator communities (Marzluff et al. 2006, Prange and Gehrt 2004a), food resources (Chace and Walsh 2006, Leston and Rodewald 2006), and species interactions (Borgmann and Rodewald 2004, Rodewald et al. 2010). These factors may differentially impact each stage of a bird's annual cycle, thereby influencing

population demography in ways that cannot be assessed purely by studying one stage at a time.

Four major stages in the annual cycle can regulate bird populations – breeding (Sillett and Holmes 2005), non-breeding/wintering (Sherry and Holmes 1996), migratory (Sillett and Holmes 2002), and post-fledging (Anders et al. 1997). Most avian studies in urban ecology have focused on the breeding season, and a growing literature indicates that lay dates are earlier, clutch sizes are smaller, nestlings are lighter, and pairs are less productive in urban landscapes (Chamberlain et al. 2009). The migratory period is comparatively less studied, though there is limited evidence that urban areas can provide resources to migrating songbirds (Rodewald and Matthews 2005, Matthews and Rodewald 2010, Craves 2009). Studies of juvenile birds during the post-fledging stage, however, have only recently occurred in urban landscapes (Whittaker and Marzluff 2009, Jackson 2010, Balogh and Marra unpublished data), despite the fact that inexperienced juveniles may be especially vulnerable to mortality (Anders et al. 1997, King et al. 2006, Rush and Stutchbury 2008). Indeed, mortality rates during the post-fledging period are high even within relatively intact or unfragmented landscapes (e.g. Anders et al. 1997, Vitz 2008).

Urban development might be expected to reduce survival of post-fledging birds due to associated changes in predator communities and habitat structure (e.g., exotic shrubs; Borgmann and Rodewald 2005). Because predators generally increase in abundance as landscapes urbanize (Rodewald in press, Marzluff et al. 2006, Prange and Gehrt 2004), fledglings might be more vulnerable to predation in urban landscapes.

Likewise, changes in habitat structure due to the presence of invasive and exotic shrubs may also influence mortality by promoting predation (via changes in predator activity or fledgling habitat use) or retarding it (via providing cover). For example, nests placed in Amur honeysuckle (*Lonicera maackii*) were depredated at higher rates than those located in native substrates (Borgmann and Rodewald 2004, Rodewald et al. 2010). The extent to which post-fledging survival is affected by urban-associated ecological changes is unknown.

While understanding the post-fledging period is important from an ecological perspective, failure to incorporate the low period-specific survival estimates (Anders and Marshall 2005) might substantially overestimate population viability models used in conservation planning. In this way, failing to appropriately account for post-fledging mortality undermines efforts to understand source-sink dynamics and make long-term population projections (Anders et al. 1997).

## OBJECTIVES

I studied the role urbanization plays in regulating bird populations during the post-fledging stage of development by investigating the survivorship and movement of two species of songbirds that model contrasting responses to urbanization: Northern Cardinal (*Cardinalis cardinalis*) and Acadian Flycatcher (*Empidonax vireescens*). The Northern Cardinal, an “urban adapter”, is a synanthropic species that is highly abundant in urban habitats during both the breeding (Leston and Rodewald 2006) and winter (Atchison and Rodewald 2006) seasons. Moreover, cardinal annual survivorship, productivity and condition are similar between rural and urban sites, suggesting that urbanization does not impact fitness (Rodewald and Shustack 2008a). Conversely, Acadian Flycatchers represent “urban avoiders” because they are less abundant (Bakermans and Rodewald 2006) and produce fewer young (Rodewald and Shustack 2008b) in urban habitats, indicating a negative response to urbanization. Using these two species as focal species I address the following questions in my thesis:

1) *Does fledgling survivorship vary over a rural-to-urban landscape gradient?*

My testable prediction was that:

Survivorship rates decline as landscapes become increasingly urbanized due to changes in predator communities and habitat structure.

2) *How does the presence of Amur Honeysuckle, an invasive shrub, affect habitat selection and survival?*

My testable predictions were that:

- a) Fledglings select habitat with extensive honeysuckle cover due to its structural complexity.
- b) Fledglings using honeysuckle face increased risk of predation, because the branch architecture of honeysuckle draws birds closer to the ground compared to individuals using other plants.
- c) Fledglings using honeysuckle face decreased risk of predation, because honeysuckle shrubs provide more dense cover compared to other plants.

3) *How is variation in survivorship explained by body condition and age?*

My testable prediction was that:

Predation rates are highest when fledglings are young and in poor condition.

4) *Which ecological factors explain variation in natal home range size?*

My testable predictions were that:

- a) Natal home range size is positively associated with individual condition at time of fledging, because birds with improved condition are more mobile.
- b) Natal home range size is inversely related to conspecific territory density at the natal site, because adult home ranges are smaller.



- c) Natal home range size is inversely related to the extent of preferred microhabitat features within the natal range, because fledglings will be less likely to move to areas perceived to have less protective cover.

5) *Which ecological factors explain variation in post-fledging dispersal timing?*

My testable predictions were that:

- a) Dispersal timing is inversely related to condition at time of fledging, because birds in good condition can better meet the energetic costs associated with dispersal.
- b) Dispersal timing is inversely related to conspecific territory density at the natal site due to intraspecific competition for resources.
- c) Dispersal timing is directly related to fledging date, because adults are more likely to reneest earlier in the breeding season and, consequently, have less time to care for previous broods.
- d) Dispersal timing is directly related to the amount of preferred microhabitat features, because fledglings will remain longer in natal ranges perceived to have greater amounts of protective cover.

## THESIS FORMAT

In the present chapter I review the current knowledge of post-fledging ecology for passerines, with emphasis on survivorship. I then explore the role urban-associated ecological factors (i.e., increased predator abundances and densities of exotic shrubs) might play in affecting fledgling survivorship. In Chapter 2 I examine how urbanization, habitat selection, and physiology explain variation in survival rates for Northern Cardinals and Acadian Flycatchers. I also describe patterns in habitat selection for the two species. In Chapter 3 I explore how a suite of physiological, social, and environmental factors explain variation in natal home range size and post-fledging dispersal timing for both species.

## BACKGROUND

The literature regarding post-fledging ecology has expanded rapidly, as recent advances in radio telemetry technology allow researchers to place transmitters on birds as small as hummingbirds (Hadly and Betts 2009). Likewise, increased interest in identifying the factors that explain dramatic declines in bird populations over the last fifty years (NABCI 2009) has directed much attention towards quantifying survival rates during what is assumed to be a highly sensitive stage of the avian life cycle (Anders and Marshall 2005). Hence, much of the post-fledging literature has focused on survivorship, with some added emphasis on habitat selection and, to a lesser extent, spatial ecology.

### *Post-fledging Survivorship*

For migratory birds, the post-fledging stage has been defined as the period between leaving the nest (i.e., fledging) and migration (Pagen et al. 2005). Past efforts to quantify juvenile survivorship during the post-fledging stage have made various assumptions, including that juvenile survivorship equals adult mortality divided by the average number of fledglings (Ricklefs 1973), half adult survivorship (Greenberg 1980), or a calculated value of 0.31 (Temple and Cary 1988). These assumptions, however, can both under- and overestimate true survivorship values, and population projections can change in trajectory depending on the assumptions used (Anders and Marshall 2005). Indeed, recent empirical evidence from field studies using telemetry indicate that high rates of fledgling mortality may regulate bird populations (eg., Anders et al. 1997, Rush and Stutchbury 2008, Moore et al. 2010),

Survivorship of fledgling birds varies over a wide range of forest, grassland, and urban landscapes (Table 1.1; Fig. 1.1) and generally improves with the age of the bird. Fledglings are most at risk of mortality within the first 5 days of fledging (Vitz 2008, Rush and Stutchbury 2008, Cohen and Lindell 2004, Naef-Daenzer et al. 2001) when up to 70% of mortality can occur (King et al. 2006). This temporal shift in survivorship has been attributed anecdotally to changes in development (i.e., visibility due to begging and feeding events) as fledglings become more mobile and less dependent on parents for resource acquisition (Anders et al. 1997, Rivera et al. 1998). Additionally, many species spend their first few days on or near the ground (White et al. 2008, Cohen and Lindell 2004), especially when fledging from ground nests (Vitz 2008). Increased mortality can

also occur when juveniles attain independence and begin dispersing from the natal range (Anders et al. 1997, Davies and Restani 2006, Sullivan 1989).

Predation is generally the principal cause of fledgling mortality (Anders et al. 1997, King et al. 2006, Vitz 2008), although identification of predators is difficult. Raptors cause the most predation events for forest and grassland birds (Lindsey et al. 1994, Anders et al. 1997, Rivera et al. 1998, Powell et al. 2000, Adams et al. 2001, Cohen and Lindell 2004, King et al. 2006, Schmidt et al. 2008, Jackson 2010, Balogh and Marra unpublished data). Other documented predators include snakes (Anders et al. 1997, Kershner et al. 2004, Vitz 2008, Jackson 2010, Balogh and Marra unpublished data), chipmunks (*Tamias striatus*; Anders et al. 1997, King et al. 2006, Vitz et al. 2008), martens (*Martes martes*; Naef-Daenzer et al. 2001), raccoons (*Procyon lotor*; Schmidt et al. 2008), domestic cats (*Felis catus*; Vitz 2008, Balogh and Marra unpublished data), other small mammals (Powell et al. 2000, Moore et al. 2010, Jackson 2008, Balogh and Marra unpublished data), and other birds such as jays and woodpeckers (Naef-Daenzer et al. 2001). There is some evidence that interactions between fledglings and potential predators can be influenced by stochastic trophic dynamics. For example, the survivorship of fledgling Wood Thrush was lower in the year following a heavy acorn crop that increased rodent abundances (Schmidt et al. 2008).

The risk of predation may be affected by physiological and reproductive constraints including body condition at time of fledging (eg. Naef-Daenzer et al. 2001; Vitz 2008), clutch size (Styrsky et al. 2005) and hatch date (Naef-Daenzer et al. 2001). A positive relationship between juvenile body condition (mass or mass corrected for body size) at time of fledging and survivorship (Saether 1989, Magrath 1991, but see Anders et

al. 1997) is reported for a variety of species, including Great Tit (*Parus major*; Perrins 1980; Naef-Daenzer et al. 2001; Monros 2002), Coal Tit (*Periparus ater*; Naef-Daenzer et al. 2001), Worm-eating Warbler (*Helmitheros vermivorus*; Vitz 2008), Ovenbird (*Seiurus aurocapillus*; Vitz 2008), Brown Thornbill (*Acanthiza pusilla*; Green and Cockburn 2001), House Sparrow (*Passer domesticus*; Ringsby et al. 1998), Dunnock (*Prunella modularis*; Davies 1986), Song Sparrow (*Melospiza melodia*; Hochachka and Smith 1991), and Collared Flycatcher (*Ficedula albicollis*; Linden et al. 1992).

Several mechanisms have been suggested for this association between body condition and juvenile survivorship. Heavier juveniles may be competitively superior to lighter conspecifics when selecting prime wintering territories during post-dependence dispersal (Perrins 1980). Likewise, heavier juveniles may be better foragers (Garnett 1981) and may be more adaptable to food shortages and foraging strategies that reduce predation risk (Magrath 1991). Moreover, experimental studies have shown that birds with less pectoral muscle mass have poor flight performance when disturbed (Veasey et al. 2000), potentially making them more susceptible to predation.

There is evidence that juvenile birds can improve their survivorship by selecting vegetation that is structurally complex, presumably because it offers cover from predators while learning to forage and undergoing the first basic molt (Rivera et al. 1998, Vitz 2008). Indeed, juvenile forest birds are abundant in early successional stands (Pagen et al. 2000; Rappole and Ballard 1987) and regenerating clearcuts (Vitz and Rodewald 2006; Marshall et al. 2003) during the post-fledging period, including species typically considered mature forest breeders (Vitz and Rodewald 2006). A consistent finding of

post-fledging studies is that independent juveniles select habitats with markedly different structure than nest sites. Wood Thrush fledglings dispersed from natal areas in mature forest to heterogeneous mixes of early to mid-successional forest habitats (Anders et al. 1998), especially along forest edges, scrub second growth, abandoned farms, and areas defoliated by gypsy moth (Rivera et al. 1998). In New Hampshire, Ovenbird (*Seiurus aurocapillus*) fledglings used areas with more complex vegetative structure within the first three meters and fewer large trees when compared to nest sites (King et al. 2006). Similarly, Ovenbirds and Worm-eating Warblers selected sites with 1.5 times more woody stems than at randomly selected plots (Vitz 2008). Hooded Warbler (*Wilsonia citrina*) fledglings used habitat with more vegetative complexity and cover (Rush and Stutchbury 2008), and Swainson's Thrushes (*Catharus ustulatus*) selected areas with dense shrub cover and few trees (White et al. 2005). In Costa Rica White-throated Robins (*Turdus assimilis*) that fledged in pastures moved more quickly to the surrounding forest than those that fledged in coffee plantations. Young robins in coffee plantations spent more time in their natal ranges, indicating a preference for vegetative cover (Cohen and Lindell 2004). Grassland species exhibited similar preferences for enhanced cover during the post-fledgling period. Dickcissel (*Spiza americana*) survival was directly related to the amount of forb growth at the nest site level (Berkeley et al. 2007). Botteri's Sparrow (*Aimophila botterii*) fledglings used patches of grass that were higher and denser than those sampled in random plots (Jones and Bock 2005). This consistent pattern of using complex vegetation suggests that juvenile birds select habitats to minimize risk of predation. The contrast between generally more mature, open nesting habitat and more

successional, denser post-fledging habitat indicates that forest birds require a heterogeneous forest landscape throughout their annual life cycle.

#### *Urbanization and the post-fledging stage*

Given the influential roles predation and habitat selection play in regulating fledging survivorship, urban-associated changes in predator communities and invasions of exotic shrubs are likely influential. Because predation largely drives fledgling survivorship (Anders et al. 1997, Naef-Daenzer et al. 2001, King et al. 2006, Vitz 2008), there is strong reason to expect that urban-associated changes in predator abundance (e.g., Sorace 2002, Chace and Walsh 2006, Rodewald in press) and distribution (Prange and Gehrt 2004, Mannan and Boal 2000, Rutz 2008) will negatively impact fledgling survival rates. For example, raccoons heavily use anthropogenic food sources (Prange and Gehrt 2004) and are recorded at higher densities in urban areas due to increased survival and recruitment rates (Prange et al. 2003). Likewise, avian predators tend to increase territory density and reduce home range size in urban areas (Mannan and Boal 2000, Rutz 2008). In particular, avian and mammalian predators increase in abundance as landscapes become more urbanized within my study system (Rodewald in press, Rodewald et al. in review).

A diverse suite of predators have been observed depredating nests, though almost nothing is known about their interactions with fledglings. Confirmed nest predators in my study system include raccoons, domestic cats, squirrels (fox, *Sciurus niger*, gray, *Sciurus carolinensis*, red, *Tamiasciurus hudsonicus*), raptors such as hawks (*Buteo spp.*, *Accipiter spp.*) and owls, corvids such as blue jays (*Cyanocitta cristata*) and

crows (*Corvus brachyrhynchos*), grackles (*Quiscalus quiscula*), cowbirds (*Molothrus ater*), and snakes (Kearns and Rodewald unpublished data). Confirmed fledgling predators in urban systems include primarily domestic cats (Balogh and Marra unpublished data) and hawks (Whittaker and Marzluff 2009, Jackson 2010), in addition to snakes (Jackson 2010) and mammals (Whittaker and Marzluff 2009, Balogh and Marra unpublished data, Jackson 2010).

Urban landscapes provide a unique opportunity to understand how plant-animal interactions mediate avian demography. Because landscape composition and configuration contribute strongly to patterns of invasion by exotic plants (Bartuszevige et al. 2006), the abundance of invasive species is correlated with proximity to developed areas (Hutchinson and Vankat 1997, Barton et al. 2004, Borgmann and Rodewald 2005). Hence, birds in urban landscapes actively exploit invasive plants for cover (Remes 2003), nesting substrate (Borgmann and Rodewald 2004) and forage (Bartuszevige and Gorchov 2006). Because invasive plants have propagated quickly and extensively (Theoharides and Dukes 2007), invasive species may act as “ecological traps” (*sensu* Gates and Gysel 1978) that regulate avian reproductive success (Schmidt and Whelan 1999, Remes 2003, Ortega et al. 2006, Nordby et al. 2009). Indeed, reduced survival of nests located in exotic compared to native plants has been reported for American Robin (*Turdus migratorius*), especially when using honeysuckle (Schmidt and Whelan 1999, Borgmann and Rodewald 2004, Rodewald et al. 2010). The high vulnerability of nests placed in exotic shrubs has been attributed both to plant architecture that makes nests more accessible (Schmidt and Whelan 1999, Borgmann and Rodewald 2004) and reduced



heterogeneity in nest placement within the habitat patch (Rodewald et al. 2010). The demonstrated affinity that fledglings have for structurally complex vegetation might promote selection of invasive shrubs, such as honeysuckle, that provide a perceived level of extensive cover. How invasive shrubs influence fledgling survivorship is unknown.

### *Post-fledging Spatial Ecology*

The area used by fledglings after leaving the nest has been termed “the post-fledging range” and includes the area used by fledglings prior to and after reaching parental independence (Anders et al. 1998). The natal home range consists only of the area used before individuals make extended movements to distinct dispersal areas (White and Faaborg 2008) and, therefore, is usually smaller than the post-fledging range. Home range is a useful estimate of spatial use for animals and is generally defined as the extent of area with a defined probability of occurrence of an animal during a specific time period (Kernohan et al. 2001). The few studies to quantify natal and post-fledging home range size have shown variation within and among species: Swainson’s Thrush – 2 ha (White and Faaborg 2008), Wood Thrush (*Hylocichla mustelina*) – 2.6 – 24.8 ha (Anders et al. 1998), Ovenbird – 5.02 ha (Vitz 2008), Worm-eating Warbler – 10.36 ha (Vitz 2008). Variation in home range size has been attributed to distribution of food resources (White and Faaborg 2008), habitat utilization (Anders et al. 1998), and behavior (Anders et al. 1998, Rivera et al. 1998, White and Faaborg 2008). For example, whereas many parents care for young in one “stationary” natal area, some Wood Thrush and Swainson’s Thrush broods move among two or more natal areas in what is called a “drifting” range (Anders et al. 1998, Rivera et al. 1998, White and Faaborg 2008). In particular, fledgling

Swainson's Thrushes spend less time on the natal range when originating from "drifting" broods (White et al. 2008).

Home range size is related to metabolic and foraging requirements and is thereby larger for predatory animals and those with high metabolisms (McNab 1963, Schoener 1968). Because fledglings theoretically occupy a subset of parental home ranges during the dependent period, natal home ranges should grow as fledglings became more mobile and able to use more of the parental range. Indeed, many post-fledging studies have shown either increased daily movements farther from the nest (Cohen and Lindell 2004, Kershner et al. 2004, Vitz 2008, Adams et al. 2001) or increased daily movements within the nest area (Berkeley et al. 2007, Wells et al. 2008, White and Faaborg 2008), which indicate that fledgling home ranges generally increase with time.

Once independent, fledglings move from the natal area to one or more dispersal areas (i.e., "post-fledgling dispersal"; Anders et al. 1998, Cohen and Lindell 2004, White and Faaborg 2008), which initiates the process of natal dispersal and the eventual movement to the site of first potential reproduction (Greenwood and Harvey 1982). Dispersal timing varies among species but generally occurs between three and five weeks after fledging when fledglings permanently leave the natal area through long linear movements (Anders et al. 1998, Cohen and Lindell 2004, Lang et al. 2002, Wells et al. 2008, Vitz 2008) and when parental interaction is no longer observed (Rivera et al. 1998, White and Faaborg 2008).

How post-fledging movements change in urban landscapes is relatively unknown. Adult mammals and birds of prey within urban areas generally have smaller home ranges

and move less compared to individuals in undeveloped landscapes. This pattern has been observed for red foxes (*Vulpes vulpes*; Adkins et al. 1998), coyotes (*Canis latrans*; Atwood et al. 2004, Grindler et al. 2001), key deer (*Odocoileus virginianus clavium*; Harveson et al. 2007), white-tailed deer (*Odocoileus virginianus*; Kilpatrick and Spohr 2000), northern raccoons (Prange and Gehrt 2004), Cooper's Hawk (*Accipiter cooperii*; Mannan and Boal 2000), and Northern Goshawk (*Accipiter gentilis*; Rutz 2006) and is attributed to novel spatial arrangements of prey resources and/or anthropogenic food sources. One study of a reptile, the Gila monster (*Heloderma suspectum*), detected no urban-associated change in home range size, although daily movements were smaller in urban areas (Kwiatkowski et al. 2008).

There is limited evidence that juvenile mobility can vary within an urbanizing landscape depending on the life history of the focal species and scale of the investigation (Whittaker and Marzluff 2009), but, overall, almost nothing is known about fledgling movement ecology in urban environments. Studies of birds in fragmented forest landscapes provide some insight as to how birds might move in similarly fragmented urban systems. For instance, Hooded Warbler family groups never left patches within a forested landscape during the period of dependency (Rush and Stutchbury 2008). Adult Ovenbirds attending fledglings were less likely than adults without young to move between fragments in an agricultural landscape (Bayne and Hobson 2001). Likewise, juvenile Ovenbirds captured in regenerating clearcuts and experimentally translocated to intact forest moved farther from their release site than birds released in clearcuts (Vitz 2008). Adults and juveniles of several forest-breeding species with different life history

strategies preferred moving through forested corridors than across gaps during the breeding and post-fledging periods (Desrochers and Hannon 2003, Haas 1995).

My two focal species, Northern Cardinal and Acadian Flycatcher, have two different life history strategies that may cause differential movement responses in an urban landscape. Acadian Flycatchers are migratory, feed exclusively on arthropods via sallying events, generally breed in large tracts of mature forests (Whitehead and Taylor 2002) and decline in number as landscapes urbanize (Bakermans and Rodewald 2006, Rodewald and Shustack 2008b). Cardinals do not migrate, feed on a variety of food resources, and are known to breed within a diverse assortment of habitats, including the urban matrix (Halkin and Linville 1999). During the non-breeding (winter) seasons, cardinals preferentially use urban landscapes over rural landscapes. Specifically, abundance of cardinals is 1.7 times higher in urban sites when breeding, whereas in winter, abundances rise to 4 times those found in rural sites, suggesting that cardinals from rural areas may be moving to urban forests to take advantage of landscape features that include greater numbers of fruits and bird-feeders, more vegetative cover, and higher temperatures (Leston and Rodewald 2006).

Differences in migratory status between my focal species also may affect dispersal timing. Acadian Flycatchers face energetic and temporal constraints associated with undergoing the first-basic molt prior to accumulating fat for long-distance migration (Morton 1991, Whitehead and Taylor 2002). Once independent, Acadian Flycatchers juveniles should disperse quickly to a discrete “dispersal range” where they can gain sufficient resources for molt and migration. Conversely, cardinals are not energetically

and temporally constrained by migration and do not require the same rapid accumulation of fat stores. Their dispersal movements are expected to be influenced by gradual changes in habitat structure and food resources, thereby producing large “dispersal ranges” that vary temporally in size.

Finally, because home range size is positively related to an animal’s metabolic requirements (McNab 1963), home range size should be related to the spatial arrangement of an animal's primary food resources. Diets of Northern Cardinal and Acadian Flycatcher during the period of parental dependence consist primarily of insects and, for Cardinals, expand to include fruits and seeds upon reaching independence (Halkin and Linville 1999, Whitehead and Taylor 2002). Predicting how movement behavior of fledglings responds to urbanization is difficult, because ecologists have a limited understanding of responses of arthropod communities to urbanization. Arthropod biomass has been shown to decline (Bolger et al. 2000), remain stable (Fujita et al. 2008), and increase (Bakermans and Rodewald 2006) in urban areas, but these associations mask changes in community assemblages with urbanization (Fujita et al. 2008) and fragment size (Bolger et al. 2000). In general, arthropods existing at varying trophic levels are thought to respond differently to urbanization (Gibb and Hochuli 2002, McIntyre et al. 2001, McIntyre 2000).

## SIGNIFICANCE

Given the significant role predation and habitat selection play in regulating fledgling survivorship, urban-associated changes in predator communities and habitat structure are likely to have a substantial effect on post-fledging survival rates. Since high mortality rates are thought to regulate bird populations in undeveloped landscapes, exacerbated predation in urban forests likely has a deleterious impact on the viability of urban bird populations. My research is among the first to explicitly test the assumption that urbanization negatively affects fledgling survivorship. As our planet continues to urbanize, conservation will increasingly occur within human-dominated landscapes. Understanding the ways in which development influences demographic processes is important when designing and managing functional ecosystems within metropolitan areas.

Table 1.1. Estimated cumulative survivorship rates of fledgings (excluding raptors) reported in studies using radio telemetry to assess fate (i.e., not mark - recapture).

Survivorship time period (Days Post-fledging), landscape, and location are given.

\*Studies included juveniles from unknown nests captured after reaching independence.

\*\*Study did not standardize days post-fledging across individual.

Species	Cumulative Survivorship	Days Post-fledging	Landscape	Location	Citation
Great-spotted Cuckoo ( <i>Clamator glandarius</i> )	0.63	59	Mixed forest/agriculture	Spain	Soler et al. 1994
Middle-spotted Woodpecker ( <i>Dendrocopos medius</i> )	0.359	84	Forest	Spain	Robles et al. 2007
American Crow ( <i>Corvus brachyrhynchos</i> )	0.54	365	Urban	Washington, USA	Whithey and Marzluff 2005
Great Tit & Coal Tit ( <i>Parus major</i> & <i>Pariparus ater</i> )	0.53	20	Forest	Switzerland	Naef-Daenzer et al. 2001
Puff-throated Bulbul ( <i>Alophoixus pallidus</i> )	0.61	56	Forest	Thailand	Sankamethawee et al. 2009
Eastern Bluebird ( <i>Sialis sialis</i> )	0.654	40	Urban	Virginia, USA	Jackson 2010
Western Bluebird ( <i>Sialia mexicana</i> )	0.64	20	Forest	Arizona, USA	Wightman 2009
Swainson's Thrush ( <i>Catharus ustulatus</i> )	0.599	55	Mixed forest/scrub	California, USA	White 2005
Swainson's Thrush ( <i>Catharus ustulatus</i> )*	0.99 - 0.93	*	Urban	Washington, USA	Whittacker and Marzluff 2009
Wood Thrush ( <i>Hylocichla mustelina</i> )	0.432	56	Forest	Missouri, USA	Anders et al. 1997
Wood Thrush ( <i>Hylocichla mustelina</i> )	0.68	90	Forest	Missouri, USA	Fink 2003
Wood Thrush ( <i>Hylocichla mustelina</i> )**	0.752	**	Forest	Georgia, USA	Powell et al. 2000
Wood Thrush ( <i>Hylocichla mustelina</i> )*	0.79	*	Forest	Virginia, USA	Rivera et al. 1998
Wood Thrush ( <i>Hylocichla mustelina</i> )	0.752	21	Forest	New York, USA	Schmidt et al. 2008
White-throated Robin ( <i>Turdus assimilis</i> )	0.67	21	Mixed forest/agriculture	Costa Rica	Cohen and Lindell 2004
American Robin ( <i>Turdus migratorius</i> )*	0.19 - 0.50	*	Urban	Washington, USA	Whittacker and Marzluff 2009
Gray Catbird ( <i>Dumetella carolinensis</i> )	0.10 - 0.45	63	Urban	Maryland, USA	Balough and Marra in review
Gray Catbird ( <i>Dumetella carolinensis</i> )	0.6	84	Mixed forest/scrub	Indiana, USA	Maxted 2001
Worm-eating Warbler ( <i>Helmitheros vermivorus</i> )	0.67	31	Forest	Ohio, USA	Vitz 2008
Ovenbird ( <i>Seiurus aurocapillus</i> )	0.63	38	Forest	New Hampshire, USA	King et al. 2006
Ovenbird ( <i>Seiurus aurocapillus</i> )	0.65	51	Forest	Ohio, USA	Vitz 2008
Hooded Warbler ( <i>Wilsonia citrina</i> )	0.19	28	Forest	Pennsylvania, USA	Rush and Stutchbury 2008
Yellow-breasted Chat ( <i>Icteria virens</i> )	0.39	56	Mixed forest/scrub	Indiana, USA	Maxted 2001
Spotted Towhee ( <i>Pipilo maculatus</i> )*	0.72 - 0.83	*	Urban	Washington, USA	Whittacker and Marzluff 2009
Lark Bunting ( <i>Calamospiza melanocorys</i> )	0.367	20	Grassland	Colorado, USA	Adams et al. 2001
Song Sparrow ( <i>Melospiza melodia</i> )*	0.80 - 0.93	*	Urban	Washington, USA	Whittacker and Marzluff 2009
Rose-breasted Grosbeak ( <i>Pheucticus ludovicianus</i> )	0.62	21	Forest	Ontario, Canada	Moore et al. 2010
Dickcissel ( <i>Spiza americana</i> )	0.33	30	Grassland	Nebraska/Iowa, USA	Berkeley et al. 2007
Dickcissel ( <i>Spiza americana</i> )	0.56	58	Grassland	Missouri, USA	Wells et al. 2008
Eastern Meadowlark ( <i>Sturnella magna</i> )	0.57	72	Grassland	Missouri, USA	Wells et al. 2008

Table 1.1



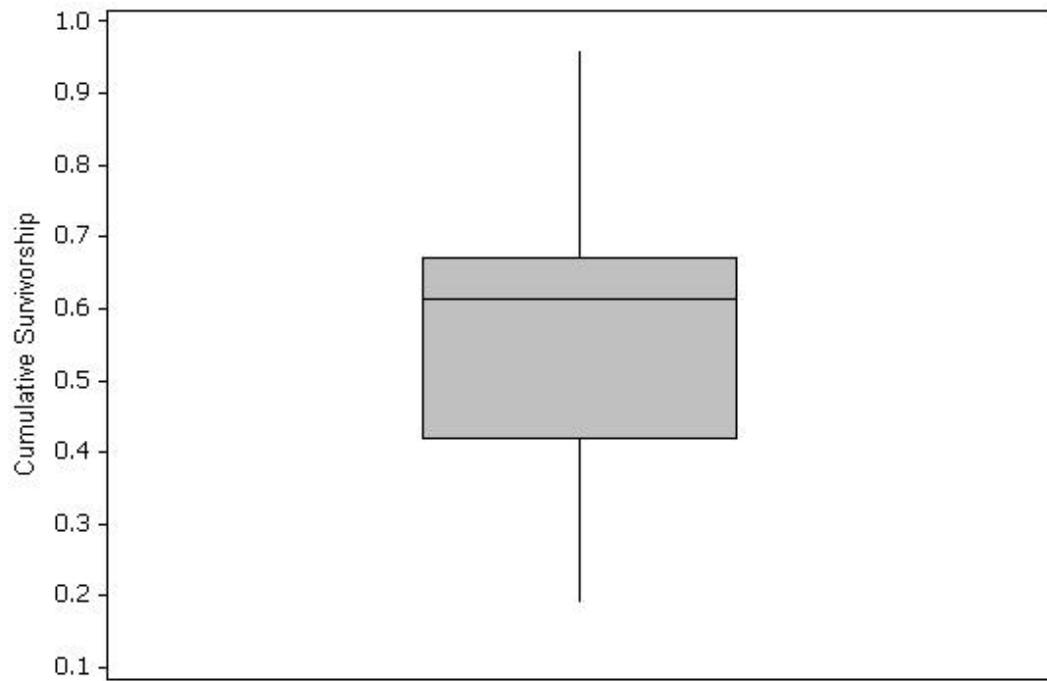


Fig. 1.1. Distribution of cumulative survivorship estimates ( $n = 30$ ) for juvenile birds (excluding raptors) during the post-fledging stage of development. Data describe 23 species from 23 studies detailed in Table 1.1. For estimates consisting of a range, averages were derived.

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## CHAPTER 2

### POST-FLEDGING SURVIVORSHIP AND HABITAT SELECTION OF SONGBIRDS ACROSS A RURAL-TO-URBAN LANDSCAPE GRADIENT

#### Abstract

Despite a growing literature regarding the demography of breeding birds in urbanizing landscapes, the post-fledging period remains poorly understood. Because novel ecological factors including abundant predator communities and invasive exotic shrubs are associated with urbanization, I asked 1) How does post-fledging survivorship vary across a rural-to-urban landscape gradient, and 2) To what extent does Amur honeysuckle (*Lonicera maackii*), an invasive exotic shrub, influence patterns of survivorship and habitat selection? During the 2008 – 2009 breeding seasons I placed radio transmitters on fledgling Northern Cardinals (*Cardinalis cardinalis*;  $n = 45$ ) and Acadian Flycatchers (*Empidonax virescens*;  $n = 21$ ) occupying riparian forest stands embedded within a rural-to-urban landscape in central Ohio. While predation was the primary cause of mortality for both species, cumulative

survivorship ( $\pm$  SE) for flycatchers ( $0.720 \pm 0.097$ ; 22 days) was 1.6 times that of cardinals ( $0.440 \pm 0.077$ ; 71 days). My results further indicate that urbanization did not negatively influence survival for either species and actually improved cardinal survivorship during the initial three days post-fledging when mortality rates were highest. Although cardinals strongly selected for complex understory vegetation that in turn improved their survivorship, honeysuckle did not specifically influence survival patterns. Collectively, my results suggest that ecological changes associated with urbanization can have little effect on fledgling survivorship within remnant forests. Rather, urban forests may provide suitable habitat for juvenile birds living within metropolitan areas.

## Introduction

The process of urbanization can profoundly alter a suite of ecological factors, including food and cover resources (Hutchinson and Vankat 1997, Barton et al. 2004, Borgmann and Rodewald 2005), microclimate (Shochat et al. 2006), and predator populations (Rodewald in press, Marzluff et al. 2006, Chace and Walsh, 2006, Prange and Gehrt 2004), that collectively influence bird populations. Nevertheless, in stark contrast to the rich literature on urban bird communities (e.g., Beissinger and Osborne 1982, Rodewald and Bakermans 2006), demographic studies of urban birds remain uncommon, and little is known about the demographic processes operating within metropolitan areas (Shochat et al. 2006). Because the few demographic studies conducted within urban systems to date have focused on adult survival (Rodewald and

Shustack 2008a, b) and reproductive productivity (Chamberlain et al. 2009), juvenile survival remains virtually unexplored (but see Whittaker and Marzluff 2009, Jackson 2010, Balogh and Marra unpublished data), leaving a large gap in our understanding of avian population ecology in urban systems.

The post-fledging period may represent the most sensitive stage of the avian life cycle (Anders and Marshall 2005), in part, because birds have limited flight capabilities and are parentally dependent (Anders et al. 1997, Rivera et al. 1998). Indeed, fledgling mortality is high for a wide variety of passerine species in both forested and non-forested landscapes (e.g., Anders et al. 1997, Rush and Stutchbury 2008, Vitz 2008). Daily survivorship generally improves with fledgling age, and birds are most at risk during the first 5 days after fledging (Vitz 2008, Rush and Stutchbury 2008, Cohen and Lindell 2004, Naef-Daenzer et al. 2001) when up to 70% of observed juvenile mortality can occur (King et al. 2006). While various reproductive, physiological, and environmental factors, such as brood size (Styrsky et al. 2005), body condition (Naef-Daenzer et al. 2001, Vitz 2008), starvation (Sullivan 1989, Jackson 2010), disease (Jackson 2010, I. Ausprey, pers. obs.) and exposure (I. Ausprey, pers. obs.), can influence fledgling survivorship, predation has been implicated as the primary cause of mortality (Anders et al. 1997, King et al. 2006, Vitz 2008). Identified predators of fledglings include raptors (Lindsey et al. 1994, Anders et al. 1997, Rivera et al. 1998, Powell et al. 2000, Adams et al. 2001, Cohen and Lindell 2004, King et al. 2006, Schmidt et al. 2008, Jackson 2010, Balogh and Marra unpublished data), snakes (Anders et al. 1997, Kershner et al. 2004, Vitz 2008,

Jackson 2010, Balogh and Marra unpublished data), chipmunks (*Tamias striatus*; Anders et al. 1997, King et al. 2006, Vitz et al. 2008), raccoons (*Procyon lotor*) (Schmidt et al. 2008), and domestic cats (*Felis catus*) (Vitz 2008, Balogh and Marra unpublished data).

While urban environments pose many risks for fledgling birds, two ecological factors associated with urbanizing landscapes seem particularly influential. First, numbers of likely predators are positively associated with urbanization (Rodewald in press, Chamberlain et al. 2009, Sorace 2002) and may exacerbate predation risk. Domestic cats, in particular, can have devastating impacts on fledglings living within the urban matrix (Balogh and Marra unpublished data). Second, urban associated invasions of exotic plants may affect fledgling survivorship by changing vegetation structures in ways that either (1) provide additional cover or (2) act as “ecological traps” (*sensu* Gates and Gysel 1978) that facilitate the access of fledglings to predators. For example, American Robin (*Turdus migratorius*) and Northern Cardinal nests located in exotic plants had lower daily survivorship rates compared to those in native plants (Schmidt and Whelan 1999, Borgmann and Rodewald 2004, Rodewald et al. 2010). Because fledglings are known to select landscapes with structurally complex vegetation, such as early-successional forest (Rappole and Ballard 1987, Pagen et al. 2000, Marshall et al. 2003, Vitz and Rodewald 2006), and microhabitats rich with shrub cover and abundant saplings (Rush and Stutchbury 2008, Vitz 2008), fledglings also might be expected to select invasive shrubs that provide a perceived

level of extensive cover. How invasive plants influence fledgling survivorship is unknown.

I studied how post-fledging survivorship of two songbird species changed along a rural-to-urban landscape gradient. In addition, I examined how an exotic invasive shrub, Amur honeysuckle, associated with urban land uses in my study area, might influence patterns of habitat use and survival. Based on the literature and previous experience with the study system, I made the following three predictions: (1) Fledgling survivorship declines with increasing urbanization surrounding riparian forests, presumably due to increased abundance of predators, (2) Because fledglings are attracted to structurally complex habitats, they preferentially use microhabitats with extensive honeysuckle cover, (3) Use of honeysuckle affects survivorship by either (a) increasing predation risk as fledglings are drawn closer to the ground or (b) deterring predation by providing protective cover.

## Methods

*Study Area.* I conducted research in 26 mature riparian forest fragments located within the Columbus metropolitan area of Franklin and Delaware Counties, Ohio. Fledglings were tracked in 21 of these sites. Fragments consisted of mature forests of similar size, shape, and spatial configuration that were > 2 km apart (Rodewald and Shustack 2008b). Plant communities consisted of a diversity of trees and woody understory plants including sycamore (*Plantanus occidentalis*), boxelder (*Acer*



*negundo*), sugar maple (*A. saccharum*), black walnut (*Juglans nigra*), ash (*Fraxinus spp.*), American hackberry (*Celtis occidentalis*), Amur honeysuckle, common spicebush (*Lindera benzoin*), tall pawpaw (*Asimina triloba*), and Ohio buckeye (*Aesculus octandra*).

Landscape composition within a 1 km radius circle surrounding each site was quantified by analyzing digital orthophotos (2002-04) and building data from Franklin and Delaware Counties. Other studies have shown strong associations between bird communities and this 1 km scale (Tewksbury et al. 1998, Saab 1999, Rodewald and Yahner 2001, Rodewald and Bakermans 2006). The first principal component of a principal components analysis examining developed features explained 80% of the variation among sites (eigenvalue = 3.99) (Rodewald and Shustack 2008b). Factor 1, referred to here as the “urban index”, loaded positively for number of buildings (0.92), percent road cover (0.94), pavement (0.90), and lawn (0.88), but loaded negatively for percent agricultural cover (-0.83) (Rodewald and Shustack 2008b). The urban index was not correlated with forest width, thereby avoiding any confounding between habitat area and urbanization (Rodewald and Shustack 2008b).

*Study Species.* I studied two species that respond differently to urbanization: Northern Cardinal and Acadian Flycatcher. The Northern Cardinal, an “urban adapter”, is a synanthropic species that occupies urban forests in higher densities than in rural forests during the breeding (1.7 times higher) and nonbreeding (4.0 times higher) seasons (Leston and Rodewald 2006). Moreover, annual survivorship, productivity and condition of cardinals are similar between rural and urban sites,

suggesting that urbanization does not impact fitness (Rodewald and Shustack 2008a). Conversely, Acadian Flycatchers represent “urban avoiders” because they are less abundant (Bakermans and Rodewald 2006), settle and initiate breeding later (Rodewald and Shustack 2008b, Shustack and Rodewald 2010), and produce fewer young (Rodewald and Shustack 2008b) in urban compared to rural forests, indicating a negative response to urbanization.

*Field Methods.* I used radio telemetry to track the fate and movements of fledgling cardinals and flycatchers. I strategically targeted nests for tagging so as to sample as much of the rural-to-urban gradient as possible, although some targeted nests were not sampled due to their height or position over water. Nests were monitored every 2-3 days for cardinals and 3-4 days for flycatchers until four days before the expected time of fledging, whereupon nests were monitored daily. Because cardinal fledglings have been observed to fledge as early as day 10 post-hatching in my system, I tagged most nestlings at age day 7-8, with the exception of two birds estimated to be 9-10 days old. For Acadian Flycatchers, nestlings were tagged on the day before or on their expected fledgling date, which usually was day 13-14. Nearly all flycatchers left the nest within two hours after tagging. Therefore, I attempted to tag nestlings at the latest date possible before fledging when I estimated that they had maximally developed.

I used a modified figure-8 harness made of a cotton-nylon elastic blend to attach transmitters (Rappole and Tipton 1991). To avoid issues surrounding lack of independence I randomly selected one nestling of sufficient mass within each nest for

tagging. Cardinal tags weighed on average 5.8% of the fledgling's mass (tag mass: 1.45g, BD-2, Holohil Systems Ltd.) and had a battery life of 9 weeks ( $n = 43$ ) and 5 weeks ( $n = 2$ ). Flycatcher tags weighed on average 4.8% of each fledgling's body mass and had a battery life of 16-21 days (tag mass: 0.47g and 0.6g, BD-2N, Holohil Systems Ltd.). Transmitters are widely used to assess animal movements (eg. Marzluff and Millspaugh 2001, Kenward 2001) and have been shown to have little impact on individual condition (Rae 2009) or behavior (Naef-Daenzer 1993). In addition, two cardinals were identified without their transmitters a year following tagging, indicating that they had successfully dropped their tags.

All nestlings from each nest received one numeric USGS aluminum band and three colored plastic bands. Immediately after removal from the nest, I weighed each nestling with a Pesola spring scale (0.05g accuracy) and measured the length of the right tarsus using standard procedures (Pyle 1997). Processing time from the point of removing the first nestling to the replacement of the last nestling varied between 15 and 60 minutes depending on the number of nestlings.

During relocation events every 1-2 days, I visually confirmed the identity of tagged fledglings through radio telemetry homing techniques and by resighting color bands. At each relocation point I recorded the plant species used and the estimated height of the individual at first detection. So as to avoid detection bias due to observer-influenced behavior, I only recorded this information for fledglings that had not moved in response to my presence.

I considered a fledgling to be depredated if 1) remains were found with the transmitter or leg bands, 2) blood, scat or scent was detected on or near the transmitter, 3) tooth or beak marks were imprinted in the transmitter housing, 4) the transmitter was buried, or 5) the transmitter or leg bands were found in association with a likely predator. If I found no direct evidence of predation but failed to detect the fledgling during hour-long searches on the relocation day and the following day, I also concluded that the fledgling had been depredated. This assumption was based on extensive field observations indicating that most mortality occurred early during the post-fledgling period when fledglings are dependent upon parents and exhibit behavioral cues (e.g., loud begging) obvious to a trained observer and was invoked for only 5 individuals that disappeared within the first week post-fledgling.

I measured microhabitat characteristics at relocation points daily for flycatchers and every 2-3 days for cardinals due to time constraints. I only surveyed vegetation at points for which the bird was visually located. Vegetation was assessed using a modified version of the James and Shugart (1970) method within 0.04-ha circles centered at the relocation point and at a randomly derived paired plot 50 m away, as well as at nest sites. I visually estimated average canopy height, average canopy cover, average honeysuckle cover, average cover of the native shrub layer (<4 m), average cover of multiflora rose (*Rosa multiflora*) and other invasive shrubs, and I counted numbers of woody stems >3 cm diameter at breast height (DBH). Stem counts were grouped into four classes: saplings (3-8 cm DBH), small trees (8-23 cm DBH), medium trees (23-38 cm DBH), and large trees (>38 cm DBH).

*Analysis.* Because I wanted to understand the relative performance of a suite of biologically-relevant factors in explaining survivorship, I used Program MARK Known-fate models rather than the Kaplan-Meier product estimator. I used an information-theoretic framework that compares relative weight of evidence for multiple models using Akaike's Information Criteria ( $AIC_c$ ) corrected for small sample sizes (Burnham and Anderson 1998). The model with lowest  $AIC_c$  value was considered best, and competing models ( $<2 \Delta AIC_c$  from the top model) were considered equally plausible given the data. Akaike weights ( $\omega_i$ , weight of evidence for each model) indicated the relative support for each model and represented the likelihood that any given model was the true best model.

I first constructed a set of time-dependent models to identify the most appropriate temporal pattern of survivorship. The time-dependent model set for cardinals included fully time-dependent and constant survivorship models and models containing two survival periods (days 1 – 3 and 4 – 71), three survival periods (days 1 – 3, 4 – 7, and 8 – 71), four survival periods (days 1 – 3, 4 – 7, 8 – 14, and 15 – 71), and five survival periods (days 1 – 3, 4 – 7, 8 – 14, 15 – 21, and 22 – 71). These periods were selected based on their correspondence to mobility stages of cardinals. Cardinals have limited flight capabilities immediately after fledgling the nest (Halkin and Linville 1999), have improved but limited capabilities by the end of the first week after fledging, exhibit extensive flight ability during their second week (Wanamaker 1942), are similar to adults in flight ability by the third week, and can forage independently during the fourth week (Halkin and Linville 1999). The time-dependent

model set for flycatchers included fully time dependent and constant survivorship models and models containing two survival periods (days 1 – 7 and 8 – 21), and three survival periods (days 1 – 7, 8 – 14, and 15 – 22). I did not include a survival period less than day 7 because flycatcher fledglings are more developed than cardinals upon fledgling and exhibit advanced flight abilities comparable to adults by the second week. I included the third week as a survival period because birds were observed flycatching independent of adults during that time period.

Next, I used the top temporal model from the first analysis as the null model in a subsequent analysis of individual and habitat variables. Here, I constructed a second set of *a priori* models to explain fledgling survivorship. I included fledgling mass at time of tagging because prior studies have found positive associations between survivorship and body condition (Naef-Daenzer et al. 2001, Vitz 2008), fledgling date because fledgling survivorship can vary seasonally (Vitz 2008), average honeysuckle and native shrub cover because fledgling birds select microhabitats with complex understory vegetation (Rush and Stutchbury 2008, Vitz 2008, King et al. 2006), and average numbers of woody stems within four size classes commonly used to describe forest structure in avian field studies (Martin et al. 1997, James and Shugart 1970). Habitat variables were averaged across all relocation points for a given individual. I also included an interaction model between time and the urban index, because associations between urbanization and survival may change with fledgling age. Because fledglings are most vulnerable during the first few days after fledgling, I ran

the same models restricting the dataset to only the first time period. All model sets used the logit link function.

I examined the extent to which fledglings selected specific microhabitat features with a discriminant function analysis (DFA; PROC CANDISC, SAS Institute 2010) performed on the same habitat variables used in the survival analysis. Prior to analysis, variables were either square root or arcsine-square root transformed to approximate normal distributions. The univariate Levene's test was used to examine homogeneity of variance within each discriminating variable, which is an assumption of DFA (McGarigal et al. 2000). Because habitat variables were not strongly correlated (Table 2.1), all were included in the DFA.

## Results

*Tagged Fledglings.* Over two years, 45 cardinal and 31 flycatcher fledglings were tagged (Fig. 2.1). In 2008 I tagged 24 cardinals and 13 flycatchers from 23 and 11 nests, respectively. In 2009 I tagged 21 cardinals and 18 flycatchers from 21 and 17 nests, respectively. Because few flycatcher nests were successful in our system, I tagged a second fledgling from two flycatcher nests in 2008 and one nest in 2009. I tagged a second cardinal fledgling from one nest in 2008 because the first fledgling was depredated within the first day, and I was able to easily capture a sibling near the nest during the first day post-fledging.

*Fledgling Mortality.* Twenty-three of the 45 tagged cardinal fledglings (51%) died during the study's duration, with mammalian and avian predation accounting for 83% of total fledgling mortality (Fig. 2.2). Five of the 31 flycatchers tagged (16%) suffered mortalities, all of which were attributed to predation (Fig. 2.3). Identified or likely predators included red fox (*Vulpes vulpes*), coyote (*Canis latrans*), and red squirrel (*Tamiasciurus hudsonicus*). I encountered additional mortality events for three individuals not included in the survival or habitat selection analyses: a banded sibling of a tagged cardinal and two tagged flycatcher fledglings that fledged prematurely during a pilot study in June 2008. The cardinal was found after having been hit by a car 30 days post-fledging, and the flycatchers were found depredated by a Broad-winged Hawk (*Buteo jamaicensis*) and a domestic cat.

*Fledgling Survivorship.* Cumulative survivorship and daily survival rates varied temporally for both cardinals and flycatchers (Fig. 2.4). The top model explaining cardinal survivorship calculated a cumulative survivorship value ( $\pm$  SE) of  $0.440 \pm 0.077$  over five time periods (Table 2.2) during the 71 days post-fledging. Daily survival rates of cardinals were lowest during day 1-3 ( $0.838 \pm 0.036$ ), and varied among day 4-7 ( $0.990 \pm 0.010$ ), day 8-14 ( $0.972 \pm 0.014$ ), day 15-21 ( $0.993 \pm 0.007$ ), and day 22-71 ( $1.000 \pm 0.000$ ). Flycatcher survivorship was best explained by two models incorporating two and three time periods (Table 2.3). I chose the second-ranked model as most appropriate, because inclusion of a third time period was more consistent with field observations of behavioral development during the third week post-fledging, and it had a similar weight as the top-ranked model. Cumulative



survivorship ( $\pm$  SE) of flycatchers was  $0.720 \pm 0.097$  over 22 days. Daily survival rates were lowest during the first week post-fledging ( $0.967 \pm 0.013$ ), and remained fairly constant during the second ( $1.000 \pm 0.000$ ), and third week ( $0.988 \pm 0.012$ ). Mortality for both species was greatest immediately following fledging.

The most important variables explaining survivorship of cardinals over the length of the study were tree size classes 3-8, 8-23, and 23-38 cm DBH, which collectively had a weight of evidence of 0.529 (Table 2.4). Survival of cardinals improved with increasing numbers of saplings ( $\beta = 0.557$ , 95% CI: 0.003 – 1.111) and small trees ( $\beta = 0.492$ , 95% CI: -0.086 – 1.070), but declined with medium-sized trees ( $\beta = -0.422$ , 95% CI: -0.912 – 0.067). In particular, daily survival rates increased by 30% as saplings became more abundant. Interestingly, when I restricted analysis to the most vulnerable period (days 1-3), the urban index was included in the top model set (Table 2.6), and survival improved with increasing urbanization in the surrounding landscape ( $\beta = 0.485$ , 95% CI: -0.087 – 1.056; Fig. 2.5).

Survivorship of flycatchers was best explained by numbers of small and large trees, which were in models having a cumulative weight of evidence of 0.660 (Table 2.5). Numbers of large trees were negatively associated with flycatcher survivorship ( $\beta = -0.720$ , 95% CI: -1.233 – -0.207), whereas the number of small trees was positively associated with survivorship ( $\beta = 1.306$ , 95% CI: 0.027 – 2.585). Daily survival rates increased by 19% as small trees became more abundant. Restriction of the analysis to the initial time period (1-7 days post-fledging) did not substantially change the results (Table 2.7).

*Habitat Use and Selection.* Cardinal and flycatcher fledglings used a diverse assemblage of plant species (Tables 2.8 and 2.9). Flycatchers were found most often in boxelder (23%,  $n = 73$ ) and maple trees (*Acer spp.*) (20%,  $n = 67$ ), whereas cardinals were found predominately in honeysuckle shrubs (32%,  $n = 152$ ) and boxelder trees (14%,  $n = 68$ ).

Fledgling position in the forest canopy was associated with the presence of honeysuckle. Average fledgling height ( $\pm$  SE) was  $7.23 \pm 0.29$  m for flycatchers ( $n = 312$ ) and  $3.34 \pm 0.15$  m for cardinals ( $n = 472$ ). Flycatcher fledglings found in honeysuckle were 2.7 times lower ( $2.81 \pm 0.34$  m,  $n = 16$ ) than those found in other substrates ( $7.71 \pm 0.30$  m,  $n = 287$ ;  $t$ -test = 6.93,  $df = 18$ ,  $P < 0.001$ ). Similarly, cardinal fledglings found in honeysuckle were 2.4 times lower ( $2.13 \pm 0.09$  m,  $n = 152$ ) than those found in other substrates ( $5.18 \pm 0.20$  m,  $n = 309$ ;  $t$ -test = 14.43,  $df = 406$ ,  $P < 0.001$ ) (Fig. 2.6). Fledgling age and height were not significantly related for either flycatchers ( $\beta = -0.007$ ,  $P = 0.361$ ,  $r = 0.03$ ) or cardinals ( $\beta = 0.001$ ,  $P = 0.687$ ,  $r = 0.00$ ).

Microhabitats selected by cardinal fledglings differed from random locations (Wilks' Lambda  $_{9,46} = 0.704$ ,  $P = 0.045$ ) in that cardinals selected areas with 1.7 times more honeysuckle cover ( $F_{1,54} = 7.19$ ,  $P = 0.010$ ; Fig 2.7a) and 1.3 times more saplings ( $F_{1,54} = 5.45$ ,  $P = 0.023$ , Fig 2.7b). Microhabitats selected by flycatchers were not significantly different in structure from random locations (Wilks' Lambda  $_{9,48} = 0.819$ ,  $P = 0.332$ ), although they did marginally select for areas with more saplings ( $F_{1,56} = 3.20$ ,  $P = 0.079$ ) (Fig. 2.8).

Less vegetation surrounded nest sites than locations used by fledgling cardinals (Wilks' Lambda  $_{7,50} = 0.720$ ,  $P = 0.016$ ) and flycatchers (Wilks' Lambda  $_{7,48} = 0.534$ ,  $P < 0.001$ ). In particular, cardinal fledglings selected areas with 2.2 times more native shrub cover ( $F_{1,56} = 15.16$ ,  $P < 0.001$ ), whereas flycatcher fledglings selected areas with 3 times more honeysuckle ( $F_{1,54} = 6.26$ ,  $P = 0.015$ ) and 2.4 times more native shrub ( $F_{1,54} = 26.91$ ,  $P < 0.001$ ) cover (Fig. 2.9).

## Discussion

During the initial three days post-fledging when fledgling mortality was highest, survival of cardinals actually improved as landscapes became increasingly urban. Daily survivorship rates increased from 0.46 in the most rural forests to 0.92 in the most urban forests. Over the entire post-fledging period, however, survivorship was not strongly related to urbanization for either species. At local scales, cardinals and flycatchers were more likely to survive as the structural complexity of forests increased, particularly at understory and midstory layers, respectively. The inverse relationship between flycatcher survivorship and numbers of large trees was likely driven by a negative correlation between large and small trees.

Because many predators of fledglings are generalist species (Anders et al. 1997, Vitz 2008, Schmidt et al. 2008) known to respond positively to urbanization (Rodewald in press, Marzluff et al. 2006, Chace and Walsh, 2006, Prange and Gehrt 2004), the risk of predation for young birds has been presumed to be high in urban

areas (Whittaker and Marzluff 2009). Hence, a positive association between survivorship during the first few days post-fledging and urbanization is paradoxical given that numbers of predators were positively related to urbanization in my study system (Rodewald in press). This pattern is consistent with suggestions that urban areas may represent safety zones from predation (Shochat et al. 2006, Shochat et al. 2010), though many empirical studies of nesting success (Jokimäki et al. 2005, Phillips et al. 2005, Thorington and Bowman 2003, Jokimäki and Huhta 2000, Rodewald et al. unpublished data) and adult survival (Rodewald and Shustack 2008a, Rodewald and Shustack 2008b, Leston and Rodewald 2006) do not support this idea. Likewise, other studies have failed to demonstrate consistent associations between urbanization and fledgling survivorship. In the larger Seattle metropolitan area, juvenile mortality for four songbird species was higher in forest patches than within the suburban matrix, although fledgling age was likely a confounding factor (Whittaker and Marzluff 2009). Balogh and Marra (unpublished data) found that mortality of juvenile Gray Catbirds (*Dumetella carolinensis*) was highest in urban neighborhoods with high numbers of cats. In contrast, survival rates of Eastern Bluebird (*Sialia sialis*) fledglings in golf courses and meadows were similar across varying levels of urbanization (Jackson 2010).

Recent lines of evidence suggest that anthropogenic resource subsidies (e.g., outdoor pet food, refuse, birdfeeders) can weaken the link between predator numbers and avian demographic parameters. For example, Rodewald et al. (in revision) found that relative numbers of predators and rates of nest predation were uncoupled in urban

landscapes, though positively related in more rural landscapes. Similarly, species known to be important nest predators in rural landscapes seldom depredated nests in cities, despite occupying cities in high numbers (Chiron and Julliard 2007, Weidinger 2009). Functional responses might be especially likely in generalist predators (e.g., raccoon, opossum [*Didelphis virginiana*], skunk [*Mephitis mephitis*], and corvids) that can adjust foraging behavior in response to prey abundance (Schmidt and Whelan 1999b). Moreover, because predictable sources of anthropogenically-derived food can spatially aggregate certain predators, such as raccoons, (Prange et al. 2004), predators may be less likely to encounter fledgling birds, which are likely taken on an incidental basis rather than detected through specialized search strategies (Vigallon and Marzluff 2005, Vickery et al. 1992). Raptors, in particular, may be less likely to prey on fledglings within urban landscapes due to abundant and easy urban prey (Mannan and Boal 2000, Chernousova 2010, Adamczewska-Andrzejewska et al., 1988). Changes in resource and prey distribution can alter predator movements such that their impact varies even over relatively small spatial scales. Cats, for instance, can have devastating impacts on juvenile birds within the urban matrix (Balogh and Marra unpublished data), but some evidence shows that domestic cats preferentially select matrix habitat over vegetation fragments, suggesting that cat kills might be less pronounced within fragments (van Heezik et al. 2009).

My study provides evidence that habitat characteristics selected by juveniles promoted survival. Cardinals and, to a lesser extent, flycatchers selected microhabitats with complex understory structure – a behavior that was associated with improved

survivorship. Preference for thick vegetation by fledglings has been reported for a variety of forest and grassland birds, including Ovenbirds (*Seiurus aurocapillus*; Vitz 2008, King et al. 2005), Worm-eating warblers (*Helmitheros vermivorus*; Vitz 2008), Hooded Warblers (*Wilsonia citrina*; Rush and Stutchbury 2008), Swainson's Thrushes (White et al. 2005), White-throated Robins (*Turdus assimilis*; Cohen and Lindell 2004), Dickcissels (*Spiza americana*; Berkeley et al. 2007), and Botteri's Sparrows (*Aimophila botterii*; Jones and Bock 2005). However, few studies have explicitly linked survivorship with habitat selection. Vitz (2008) found that surviving Ovenbirds and Worm-eating Warblers in southern Ohio used microhabitats with 20% more woody stems than non-surviving individuals. Likewise, vertical vegetation structure was positively associated with Ovenbird survival in New Hampshire (King et al. 2005). Hence, my results are consistent with the general idea that habitat selection influences survivorship of fledgling birds.

The link between fledging survivorship and structural complexity may partly explain the positive relationship that I detected between cardinal survivorship and urbanization. In my system, as landscapes surrounding forests urbanized, the forest understory became more dense and dominated by the exotic and invasive Amur honeysuckle (Borgmann and Rodewald 2005, Rodewald in press). Cover by honeysuckle also was positively correlated with numbers of saplings. Although flycatchers seldom used honeysuckle or shrubs, cardinals strongly selected for microhabitats rich with honeysuckle, which resulted not only in greater cover surrounding birds, but lower perching height. Despite my initial predictions that

lowered perching height would result in increased predation by mammals, honeysuckle was not negatively associated with survivorship. In contrast to the risk that exotic shrubs pose for nests (Schmidt and Whelan 1999a, Borgmann and Rodewald 2004, Rodewald et al. 2010), the dense vegetation provided by exotics might instead prove beneficial to young birds by drawing them into areas with more protective cover.

My estimates of post-fledging survivorship rates for Northern Cardinal and Acadian Flycatcher represent among the highest (0.72 for flycatchers) and lowest (0.44 for cardinals) estimates of survivorship in the literature. The dramatic difference in survivorship between the two species is likely the consequence of different behaviors that mediate exposure to predators. Immediately after leaving the nest, flycatchers move into the forest canopy (Mumford 1964), whereas cardinals have limited flight ability and remain in shrubs near the nest (Laskey 1944, Halkin and Linville 1999). On many occasions during the first week post-fledging, cardinal fledglings were also observed begging within 1 - 2 meters of the ground (I. Ausprey, pers. obs.), a conspicuous behavior that might have attracted mammalian predators (Martin and Briskie 2009).

In my system, predation was the primary source of mortality for fledglings, and risk of mortality for Northern Cardinals and Acadian Flycatchers was greatest during the first few days after fledging. Likewise, daily survivorship was lowest during the first five days post-fledging for Rose-breasted Grosbeaks (Moore et al. 2010), Worm-eating Warblers (Vitz 2008), Ovenbirds (Vitz 2008), Hooded Warblers (Rush and

Stutchbury 2008), White-throated Robins (Cohen and Lindell 2004), and Great and Coals Tits (*Parus major* and *Periparus ater*) (Naef-Daenzer et al. 2001). Eighty percent of flycatcher and 93% of cardinal mortality occurred during the first week post-fledging (Fig. 2.3), which is similar to the 70% mortality rate King et al. (2006) reported for Ovenbirds during the initial five days. Temporal shifts in survivorship have been attributed anecdotally to behavioral development (Anders et al. 1997, Rivera et al. 1998) and the propensity of fledglings to spend their first days on the ground (White et al. 2008, Cohen and Lindell 2004), especially when fledging from ground nests (Vitz 2008). Additionally, some species experience a second peak in mortality when juveniles disperse from the natal area and attain independence (Anders et al. 1997, Davies and Restani 2006, Sullivan 1998). However, survivorship of cardinals did not change 5-7 weeks post-fledging when the majority of individuals surviving to independence dispersed from natal areas (Chapter 3).

My results suggest that forests within urban landscapes or those heavily invaded by exotic shrubs do not necessarily expose fledglings to greater mortality risk, but there are two important caveats to my findings. First, differences in avian density among sites resulted in uneven sample sizes across the urban-to-rural landscape gradient. Second, my two-year study is unlikely to sufficiently capture potential seasonal or annual variation in survival rates. Despite the fact that cardinals fledge young well into August, my sample was dominated by individuals fledged in late spring and early summer. Survivorship may vary seasonally (Vitz 2008) and annually in response to pulses in predator populations (Schmidt et al. 2008).



## Conclusion and Conservation Implications

During the two years of my study, survivorship of Northern Cardinal and Acadian Flycatcher fledglings was not strongly related to the extent of urbanization in the surrounding landscape or honeysuckle cover. Across the rural-to-urban landscape gradient, both species also improved their survivorship by selecting microhabitats that were structurally more complex than those surrounding nest sites, signifying the importance heterogeneous forests play in supporting birds throughout the breeding season. Given the important role fledgling survivorship plays in influencing population viability (Anders and Marshall 2005) and source-sink status of breeding sites (Anders et al. 1998, Rush and Stutchbury 2008, Moore et al. 2010), urban forests may contribute positively towards supporting populations of synanthropic bird species, such as Northern Cardinals. Furthermore, 29% of the cardinals that survived to independence made post-fledging dispersal movements to areas within the surrounding landscape matrix (Chapter 3). While their future breeding locations are unknown, such movements suggest that urban forests may act as sources for cardinal populations in the urban matrix where predation pressures can be more severe (Balogh and Marra unpublished data). The ability of urban forests to support songbirds during the highly sensitive post-fledging stage adds evidence to the assertion that conserving open space in urbanizing landscapes should remain a conservation priority (Dearborn and Kark 2010).

ACFL \ NOCA	Urban Index	% Cover Honeysuckle	% Cover Native Shrubs	% Cover Other Invasives	Saplings (3-8 DBH)	Small Trees (8-23 DBH)	Medium Trees (23-38 DBH)	Large Trees
Urban Index	1.00	0.29 <i>&lt;.0001</i>	0.11 <i>0.01</i>	-0.27 <i>&lt;.0001</i>	-0.19 <i>&lt;.0001</i>	-0.21 <i>&lt;.0001</i>	0.00 <i>0.97</i>	0.08 <i>0.08</i>
% Cover Honeysuckle	0.08 <i>0.13</i>	1.00	-0.38 <i>&lt;.0001</i>	-0.05 <i>0.30</i>	0.23 <i>&lt;.0001</i>	0.08 <i>0.06</i>	0.11 <i>0.01</i>	0.03 <i>0.43</i>
% Cover Native Shrubs	0.16 <i>&lt;.0001</i>	-0.26 <i>&lt;.0001</i>	1.00	-0.04 <i>0.40</i>	-0.12 <i>0.01</i>	-0.05 <i>0.27</i>	-0.16 <i>&lt;.0001</i>	-0.03 <i>0.45</i>
% Cover Other Invasive	-0.17 <i>&lt;.0001</i>	0.12 <i>0.02</i>	-0.14 <i>0.01</i>	1.00	-0.02 <i>0.63</i>	-0.06 <i>0.15</i>	0.05 <i>0.23</i>	-0.01 <i>0.89</i>
Saplings (3-8 DBH)	-0.06 <i>0.24</i>	0.41 <i>&lt;.0001</i>	0.15 <i>0.01</i>	0.19 <i>&lt;.0001</i>	1.00	0.24 <i>&lt;.0001</i>	0.05 <i>0.28</i>	-0.01 <i>0.84</i>
Small Trees (8-23 DBH)	-0.25 <i>&lt;.0001</i>	0.08 <i>0.12</i>	-0.13 <i>0.01</i>	0.19 <i>0.00</i>	0.31 <i>&lt;.0001</i>	1.00	0.13 <i>&lt;.0001</i>	-0.07 <i>0.13</i>
Medium Trees (23-38 DBH)	-0.18 <i>&lt;.0001</i>	-0.07 <i>0.22</i>	0.00 <i>0.99</i>	-0.08 <i>0.15</i>	0.22 <i>&lt;.0001</i>	0.14 <i>0.01</i>	1.00	0.15 <i>&lt;.0001</i>
Large Trees (38+ DBH)	0.07 <i>0.20</i>	-0.04 <i>0.45</i>	-0.10 <i>0.07</i>	-0.18 <i>0.00</i>	-0.26 <i>&lt;.0001</i>	-0.22 <i>&lt;.0001</i>	0.03 <i>0.53</i>	1.00

Table 2.1. Correlation matrix (Pearson's correlation coefficient) for urban index and vegetation variables measured at fledgling Northern Cardinal and Acadian Flycatcher relocation points in central Ohio, 2008-2009. *P*-values are in italics.

*n* = 43.

Model	AIC <sub>c</sub>	$\Delta$ AIC <sub>c</sub>	AIC <sub>c</sub> Weight	k	Deviance	$\phi$	SE	95% CI
$\phi_{t5}$	162.482	0.000	0.658	5	15.010	0.440	0.077	0.298 – 0.592
$\phi_{t4}$	163.895	1.413	0.325	4	18.441	0.429	0.079	0.286 – 0.586
$\phi_{t2}$	170.525	8.043	0.012	2	29.096	0.393	0.082	0.248 – 0.560
$\phi_{t3}$	172.231	9.749	0.005	3	28.791	0.398	0.082	0.252 – 0.564
$\phi.$	226.224	63.742	0.000	1	86.802	0.229	0.070	0.120 – 0.393
$\phi_{t \text{ daily}}$	289.183	126.701	0.000	71	0.000	0.430	0.079	0.287 – 0.586

Table 2.2. Northern Cardinal ( $n = 45$ ) time models using Akaike's Information Criterion corrected for small sample sizes (AIC<sub>c</sub>) as created by Program MARK known fate models. Models include those that change survivorship between different time intervals (t2, t3, t4, t5), one that assumes constant survivorship across all time intervals ( $\phi.$ ), and one that varies survivorship every day (t daily).

Model	AIC <sub>c</sub>	$\Delta$ AIC <sub>c</sub>	AIC <sub>c</sub> Weight	k	Deviance	$\phi$	SE	95% CI
$\phi_{t2}$	69.562	0.000	0.462	2	65.532	0.738	0.087	0.537-0.872
$\phi_{t3}$	69.725	0.163	0.426	3	63.664	0.720	0.097	0.499-0.868
$\phi_{.}$	72.383	2.821	0.113	1	70.373	0.675	0.100	0.459-0.836
$\phi_{t \text{ daily}}$	99.407	29.845	0.000	22	52.694	0.734	0.090	0.529-0.872

Table 2.3. Acadian Flycatcher ( $n = 31$ ) time models using Akaike's Information Criterion corrected for small sample sizes (AIC<sub>c</sub>) as created by Program MARK known fate models. Models include those that change survivorship between different time intervals ( $t_2, t_3$ ), one that assumes constant survivorship across all time intervals ( $\phi_{.}$ ), and that varies survivorship every day ( $t \text{ daily}$ ).

Table 2.4. Northern Cardinal ( $n = 43$ ) survivorship models including covariates using Akaike's Information Criterion corrected for small sample sizes ( $AIC_c$ ) as created by Program MARK known fate models. Models include one in which survivorship changes over three time intervals (t5) and others that incorporate covariates: average number of saplings 3 – 8 cm DBH (3-8), small trees 8 – 23 cm DBH (8-23), medium trees 23 – 38 cm DBH (23-38), and large trees 38+ cm DBH (38+), average percent cover of honeysuckle shrubs (honey) and native vegetation < 4m (native), fledgling mass at time of tagging (mass), fledging date (julian), fledgling mass at time of tagging restricted to the first time interval (mass1), year, and interaction between survival time period and the urban index (t5\*urban5).

	Model	AIC <sub>c</sub>	Δ AIC <sub>c</sub>	AIC <sub>c</sub> Weight	k	Deviance	φ	φ SE	95% CI	β	β SE	95% CI
O <sub>9</sub>	φ <sub>t5+3-8</sub>	152.380	0.000	0.270	6	140.304	0.463	0.083	0.310 - 0.623	0.557	0.283	0.003 - 1.111
	φ <sub>t5+8-23</sub>	153.677	1.297	0.141	6	141.602	0.464	0.082	0.313 - 0.623	0.492	0.295	-0.086 - 1.070
	φ <sub>t5+23-38</sub>	154.036	1.656	0.118	6	141.960	0.470	0.081	0.319 - 0.627	-0.422	0.250	-0.912 - 0.067
	φ <sub>t5</sub>	154.676	2.296	0.086	5	144.622	-	-	-	-	-	-
	φ <sub>t5+native</sub>	154.891	2.511	0.077	6	142.815	0.469	0.081	0.318 - 0.626	0.391	0.310	-0.218 - 0.999
	φ <sub>t5+year</sub>	155.295	2.915	0.063	6	153.219	0.470	0.081	0.319 - 0.626	-0.281	0.240	-0.752 - 0.190
	φ <sub>t5+38+</sub>	155.558	3.178	0.055	6	143.482	0.466	0.081	0.316 - 0.622	-0.272	0.247	-0.755 - 0.211
	φ <sub>t5+mass1</sub>	156.375	3.995	0.037	6	144.300	0.465	0.080	0.317 - 0.620	-0.155	0.275	-0.694 - 0.384
	φ <sub>t5+urban</sub>	156.441	4.061	0.035	6	144.365	0.463	0.080	0.315 - 0.618	0.118	0.233	-0.338 - 0.574
	φ <sub>t5+julian</sub>	156.569	4.189	0.033	6	144.493	0.463	0.080	0.315 - 0.618	0.081	0.227	-0.364 - 0.525
	φ <sub>t5+honey</sub>	156.662	4.282	0.032	6	144.587	0.463	0.080	0.315 - 0.618	0.049	0.264	-0.468 - 0.567
	φ <sub>t5+mass</sub>	156.679	4.299	0.031	6	144.603	0.464	0.080	0.316 - 0.618	0.030	0.220	-0.401 - 0.462
	φ <sub>t5*urban5</sub>	157.360	4.980	0.022	10	137.161	0.538	0.089	0.365 - 0.702	t1:0.505 t2:-1.725 t3:-0.831 t4:-1.970 t5:0.037	0.291 2.454 0.688 2.584 264.954	-0.065 - 1.076 -6.536 - 3.086 -2.180 - 0.518 -7.034 - 3.094 -519.272 - 519.347

Table 2.4

Table 2.5. Acadian Flycatcher ( $n = 31$ ) survivorship models including covariates using Akaike's Information Criterion corrected for small sample sizes ( $AIC_c$ ) as created by Program MARK known fate models. Models include one in which survivorship changes over three time intervals (t3) and others that incorporate covariates: average number of saplings 3 – 8 cm DBH (3-8), small trees 8 – 23 cm DBH (8-23), medium trees 23 – 38 cm DBH (23-38), and large trees 38+ cm DBH (38+), average percent cover of honeysuckle shrubs (honey) and native vegetation < 4m (native), fledgling mass at time of tagging (mass), fledgling mass at time of tagging restricted to the first time period (mass1), fledging date (julian), year, and interaction between survival time period and the urban index (t3\*urban3).

Model	AIC <sub>c</sub>	Δ AIC <sub>c</sub>	AIC <sub>c</sub> Weight	k	Deviance	φ	φ SE	95% CI	β	β SE	95% CI
φ <sub>t3+38+</sub>	65.644	0.000	0.388	4	57.542	0.754	0.100	0.515 - 0.898	-0.724	0.262	-1.238 - -0.210
φ <sub>t3+8-23</sub>	66.143	0.499	0.302	4	58.041	0.807	0.101	0.541 - 0.937	1.288	0.653	0.009 - 2.567
φ <sub>t3+3-8</sub>	68.824	3.180	0.079	4	60.722	0.753	0.105	0.501 - 0.902	0.827	0.551	-0.253 - 1.907
φ <sub>t3</sub>	69.725	4.081	0.050	3	63.664	0.720	0.097	0.499 - 0.868	-		
φ <sub>t3+honey</sub>	70.134	4.490	0.041	4	62.032	0.743	0.101	0.506 - 0.891	0.610	0.535	-0.437 - 1.658
φ <sub>t3+julian</sub>	70.764	5.120	0.030	4	62.662				0.376	0.376	-0.361 - 1.114
φ <sub>t3+23-38</sub>	71.451	5.807	0.021	4	63.349	0.717	0.099	0.493 - 0.869	0.233	0.430	-0.609 - 1.075
φ <sub>t3+mass</sub>	71.548	5.904	0.020	4	63.445	0.724	0.097	0.502 - 0.872	-0.178	0.379	-0.921 - 0.566
φ <sub>t3+year</sub>	71.591	5.947	0.020	5	61.437	0.777	0.098	0.536 - 0.913	0	-0.445	-0.445 - -0.445
φ <sub>t1+mass1</sub>	71.712	6.068	0.019	4	63.609	0.720	0.097	0.500 - 0.869	0.094	0.406	-0.701 - 0.889
φ <sub>t3+native</sub>	71.732	6.088	0.018	4	63.630	0.720	0.097	0.500 - 0.869	-0.071	0.385	-0.826 - 0.684
φ <sub>t3+urban</sub>	71.761	6.117	0.018	4	63.658	0.720	0.097	0.500 - 0.869	-0.027	0.372	-0.755 - 0.701
φ <sub>t3*urban3</sub>	75.825	10.181	0.002	6	63.609	0.719	0.098	0.498 - 0.868	-0.060	0.396	-0.837 - 0.717
									1.720	1298.606	-2543.547 - 2546.987
									0.185	1.072	-1.916 - 2.286

Table 2.5



Model	AIC <sub>c</sub>	$\Delta$ AIC <sub>c</sub>	AIC <sub>c</sub> Weight	k	Deviance	$\phi$	$\phi$ SE	95% CI	$\beta$	$\beta$ SE	95% CI
$\phi_{t1+8-23}$	87.281	0.000	0.184	3	81.031	0.638	0.082	0.468 - 0.780	0.708	0.428	-0.312 - 1.548
$\phi_{t1+urban}$	87.867	0.586	0.137	3	81.617	0.630	0.080	0.465 - 0.769	0.485	0.291	-0.087 - 1.056
$\phi_{t1+3-8}$	87.879	0.598	0.136	3	81.629	0.623	0.080	0.459 - 0.763	0.513	0.319	-0.113 - 1.138
$\phi_{t1+23-38}$	88.335	1.053	0.109	3	82.085	0.620	0.079	0.458 - 0.759	-0.496	0.317	- 1.118 - 0.125
$\phi_{t1}$	88.666	1.384	0.092	2	84.542	-	-	-	-	-	-
$\phi_{t1+native}$	88.978	1.697	0.079	3	82.728	0.626	0.079	0.462 - 0.765	0.434	0.347	-0.245 - 1.113
$\phi_{t1+year}$	89.030	1.746	0.077	3	82.777	0.630	0.079	0.466 - 0.769	-0.387	0.298	-0.971 - 0.198
$\phi_{t1+honey}$	89.519	2.238	0.060	3	83.269	0.622	0.079	0.460 - 0.760	0.347	0.321	-0.282 - 0.977
$\phi_{t1+38+}$	89.541	2.260	0.059	3	83.291	0.623	0.078	0.463 - 0.761	-0.302	0.262	-0.816 - 0.212
$\phi_{t1+mass}$	90.514	3.233	0.036	3	84.264	0.616	0.078	0.457 - 0.753	-0.144	0.276	-0.685 - 0.396
$\phi_{t1+julian}$	90.786	3.504	0.032	3	84.535	0.614	0.077	0.456 - 0.751	-0.022	0.276	-0.563 - 0.518

Table 2.6. Northern Cardinal ( $n = 43$ ) survivorship restricted to the first survival time period (day 1-3 post-fledging). Models include covariates using Akaike's Information Criterion corrected for small sample sizes (AIC<sub>c</sub>) as created by Program MARK known fate models. Models include one in which survivorship changes over three time intervals (t1) and others that incorporate covariates: average number of saplings 3 – 8 cm DBH (3-8), small trees 8 – 23 cm DBH (8-23), medium trees 23 – 38 cm DBH (23-38), and large trees 38+ cm DBH (38+), average percent cover of honeysuckle shrubs (honey) and native vegetation < 4m (native), fledgling mass at time of tagging (mass), fledging date (julian), and year.

Model	AIC <sub>c</sub>	Δ AIC <sub>c</sub>	AIC <sub>c</sub> Weight	k	Deviance	φ	φ SE	95% CI	β	β SE	95% CI
φ <sub>t1+8-23</sub>	55.191	0.000	0.287	3	49.057	0.852	0.082	0.615 - 0.954	1.222	0.789	-0.325 - 2.768
φ <sub>t1+38+</sub>	56.654	1.462	0.138	3	50.519	0.815	0.076	0.622 - 0.922	-0.558	0.347	-1.239 - 0.122
φ <sub>t1</sub>	56.881	1.689	0.123	2	52.814	0.792	0.075	0.608 - 0.903	-	-	-
φ <sub>t1+year</sub>	57.381	2.190	0.096	3	51.247	0.816	0.079	0.613 - 0.925	0.610	0.548	-2.146
φ <sub>t1+julian</sub>	57.912	2.720	0.074	3	51.778	0.806	0.076	0.615 - 0.915	0.415	0.407	-0.383 - 1.212
φ <sub>t1+3-8</sub>	58.421	3.230	0.057	3	52.287	0.799	0.077	0.610 - 0.910	0.347	0.520	-0.672 - 1.366
φ <sub>t1+23-38</sub>	58.836	3.644	0.046	3	52.702	0.792	0.076	0.608 - 0.904	0.143	0.432	-0.704 - 0.990
φ <sub>t1+honey</sub>	58.890	3.699	0.045	3	52.756	0.793	0.076	0.608 - 0.904	0.108	0.457	-0.788 - 1.004
φ <sub>t1+mass</sub>	58.894	3.703	0.045	3	52.760	0.792	0.076	0.608 - 0.904	0.094	0.406	-0.701 - 0.889
φ <sub>t1+urban</sub>	58.926	3.734	0.044	3	52.792	0.792	0.075	0.608 - 0.903	-0.060	0.396	-0.837 - 0.717
φ <sub>t1+native</sub>	58.947	3.756	0.044	3	52.813	0.792	0.075	0.608 - 0.903	-0.012	0.410	-0.814 - 0.791

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Table 2.7. Acadian Flycatcher ( $n = 31$ ) survivorship restricted to the first survival time period (day 1-7 post-fledging). Models include covariates using Akaike's Information Criterion corrected for small sample sizes (AIC<sub>c</sub>) as created by Program MARK known fate models. Models include one in which survivorship changes over three time intervals (t1) and others that incorporate covariates: average number of saplings 3 – 8 cm DBH (3-8), small trees 8 – 23 cm DBH (8-23), medium trees 23-38 cm DBH (23-38), and big trees 38+ cm DBH (38+), average percent cover of honeysuckle shrubs (honey) and native vegetation < 4m (native), fledgling mass at time of tagging (mass), fledging date (julian), and year.

Plant	N	%	Mean Fledgling	
			Height	SE
Amur Honeysuckle ( <i>Lonicera maackii</i> )	152	32.00	2.13	0.09
Boxelder ( <i>Acer negundo</i> )	68	14.32	4.87	0.37
Maple sp. ( <i>Acer spp.</i> )	35	7.37	8.49	0.77
Mulberry ( <i>Morus spp.</i> )	28	5.89	5.50	0.53
Grape ( <i>Vitis spp.</i> )	22	4.63	5.14	0.87
Elm sp. ( <i>Ulmus spp.</i> )	17	3.58	5.82	0.97
Hackberry ( <i>Celtis occidentalis</i> )	16	3.37	5.06	0.99
Dead Woody Matter	16	3.37	2.25	0.39
Ohio Buckeye ( <i>Aesculus glabra</i> )	15	3.16	5.80	0.55
Multiflora Rose ( <i>Rosa multiflora</i> )	14	2.95	1.93	0.13
Ground	11	2.32	0.00	0.00
Ash sp. ( <i>Fraxinus spp.</i> )	10	2.11	4.60	0.81
Black Walnut ( <i>Juglans nigra</i> )	10	2.11	6.60	1.33
Osage-Orange ( <i>Maclura pomifera</i> )	10	2.11	5.70	1.15
Unknown	9	1.89	4.89	1.12
Spicebush ( <i>Lindera benzoin</i> )	8	1.68	2.13	0.13
Hawthorn sp. ( <i>Crataegus spp.</i> )	6	1.26	4.00	0.00
<i>Malus spp.</i>	5	1.05	5.00	1.05
Ornamental Cedar spp.	3	0.63	3.67	0.88
Pawpaw ( <i>Asimina triloba</i> )	3	0.63	4.33	1.20
Black Cherry ( <i>Prunus serotina</i> )	2	0.42	3.50	0.50
Eastern Cottonwood ( <i>Populus deltoides</i> )	2	0.42	9.50	4.50
Pine sp. ( <i>Pinus spp.</i> )	2	0.42	3.50	0.50
American Basswood ( <i>Tilia americana</i> )	1	0.21	12.00	0.00
Beech ( <i>Fagus grandifolia</i> )	1	0.21	8.00	0.00
Birch sp. ( <i>Betula spp.</i> )	1	0.21	6.00	0.00
Flowering Dogwood ( <i>Cornus florida</i> )	1	0.21	3.00	0.00
Ninebark ( <i>Physocarpus spp.</i> )	1	0.21	2.00	0.00
Autumn Olive ( <i>Elaeagnus umbellata</i> )	1	0.21	2.00	0.00
Redbud ( <i>Cercis canadensis</i> )	1	0.21	4.00	0.00
Black Willow ( <i>Salix purpurea</i> )	1	0.21	1.00	0.00

Table 2.8. Plant species used by Northern Cardinal fledglings ( $n = 472$  relocation points) and mean height of fledglings when using a given plant species in central Ohio, 2008-2009.

Plant	N	%	Mean Fledgling	
			Height	SE
Boxelder ( <i>Acer negundo</i> )	73	23.40	6.75	0.41
Maple sp. ( <i>Acer spp.</i> )	62	19.87	10.26	0.76
Ohio Buckeye ( <i>Aesculus glabra</i> )	27	8.65	5.41	0.44
Elm sp. ( <i>Ulmus spp.</i> )	18	5.77	7.61	0.71
Amur Honeysuckle ( <i>Lonicera maackii</i> )	16	5.13	2.81	0.34
Hackberry ( <i>Celtis occidentalis</i> )	13	4.17	9.92	1.45
Black Walnut ( <i>Juglans nigra</i> )	10	3.21	11.50	2.24
Ash sp. ( <i>Fraxinus spp.</i> )	9	2.88	5.89	1.38
Grape ( <i>Vitis spp.</i> )	9	2.88	3.78	0.57
Ground	9	2.88	0.00	0.00
Hickory sp. ( <i>Carya spp.</i> )	8	2.56	12.50	1.18
Dead Woody Matter	8	2.56	3.88	1.61
Pawpaw ( <i>Asimina triloba</i> )	7	2.24	3.29	0.87
Oak sp. ( <i>Quercus spp.</i> )	5	1.60	10.00	4.00
American Sycamore ( <i>Platanus occidentalis</i> )	5	1.60	11.80	3.26
Autumn Olive ( <i>Elaeagnus umbellata</i> )	4	1.28	3.00	0.41
Osage-Orange ( <i>Maclura pomifera</i> )	4	1.28	14.25	2.84
Unknown	4	1.28	7.25	2.87
Mulberry ( <i>Morus spp.</i> )	3	0.96	3.67	0.88
Redbud ( <i>Cercis canadensis</i> )	3	0.96	5.00	1.00
Black Cherry ( <i>Prunus serotina</i> )	2	0.64	6.00	0.00
Hophornbeam ( <i>Ostrya virginiana</i> )	2	0.64	10.50	1.50
Blue Beech ( <i>Carpinus caroliniana</i> )	2	0.64	6.00	0.00
American Basswood ( <i>Tilia americana</i> )	1	0.32	7.00	0.00
American Bladdernut ( <i>Staphylea trifolia</i> )	1	0.32	2.00	0.00
Northern Catalpa ( <i>Catalpa speciosa</i> )	1	0.32	6.00	0.00
Eastern Cottonwood ( <i>Populus deltoides</i> )	1	0.32	5.00	0.00
Flowering Dogwood ( <i>Cornus florida</i> )	1	0.32	2.00	0.00
Hawthorn sp. ( <i>Crataegus spp.</i> )	1	0.32	3.00	0.00
Honey Locust ( <i>Gleditsia triacanthos</i> )	1	0.32	6.00	0.00
Spicebush ( <i>Lindera benzoin</i> )	1	0.32	1.00	0.00
Black Willow ( <i>Salix purpurea</i> )	1	0.32	5.00	0.00

Table 2.9. Plant species used by Acadian Flycatcher fledglings ( $n = 312$  relocation points) and mean height of fledglings when using a given plant species in central Ohio, 2008-2009.

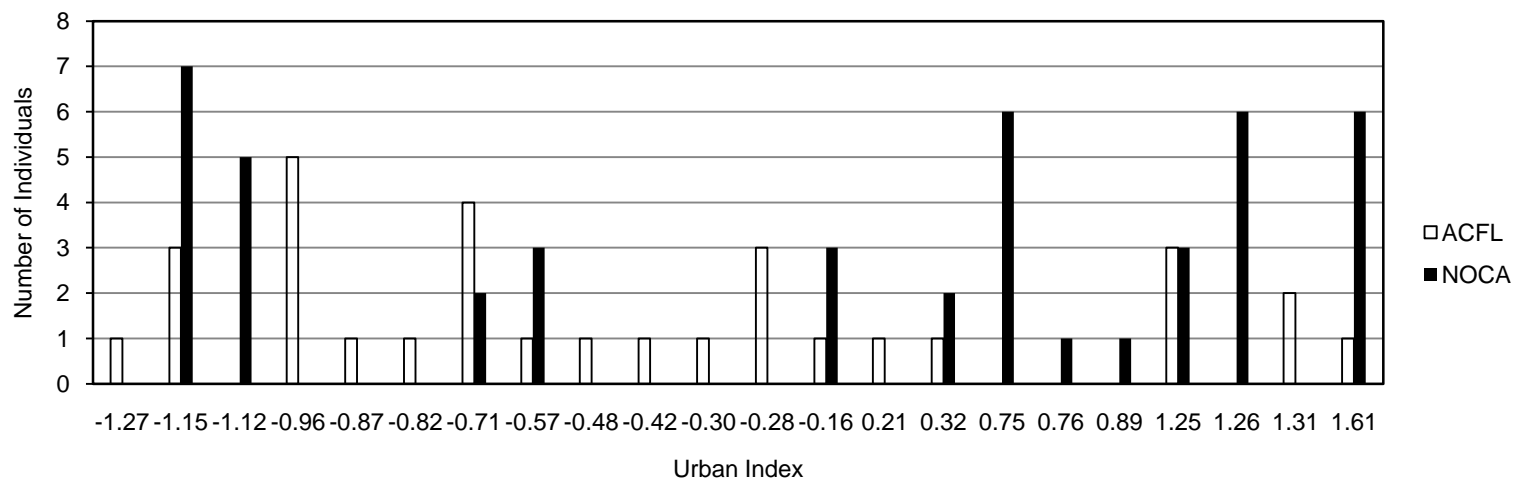


Figure 2.1. Sampling distribution of radio-tagged Northern Cardinal ( $n = 45$ ) and Acadian Flycatcher ( $n = 31$ ) fledglings in central Ohio, 2008 - 2009.

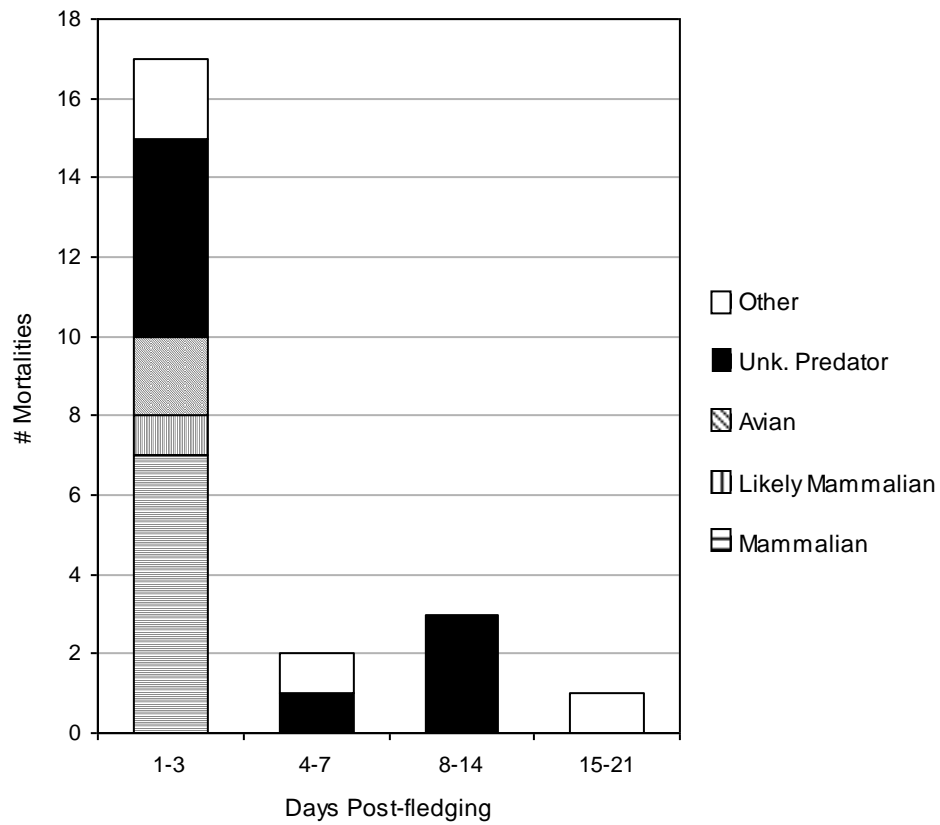


Figure 2.2. Causes of fledgling mortality for Northern Cardinals ( $n = 23$ ) within survival time periods in central Ohio, 2008-2009. Predators are classed as avian, mammalian, or unknown. The ‘Other’ category includes mortalities due to disease, drowning, and exposure.

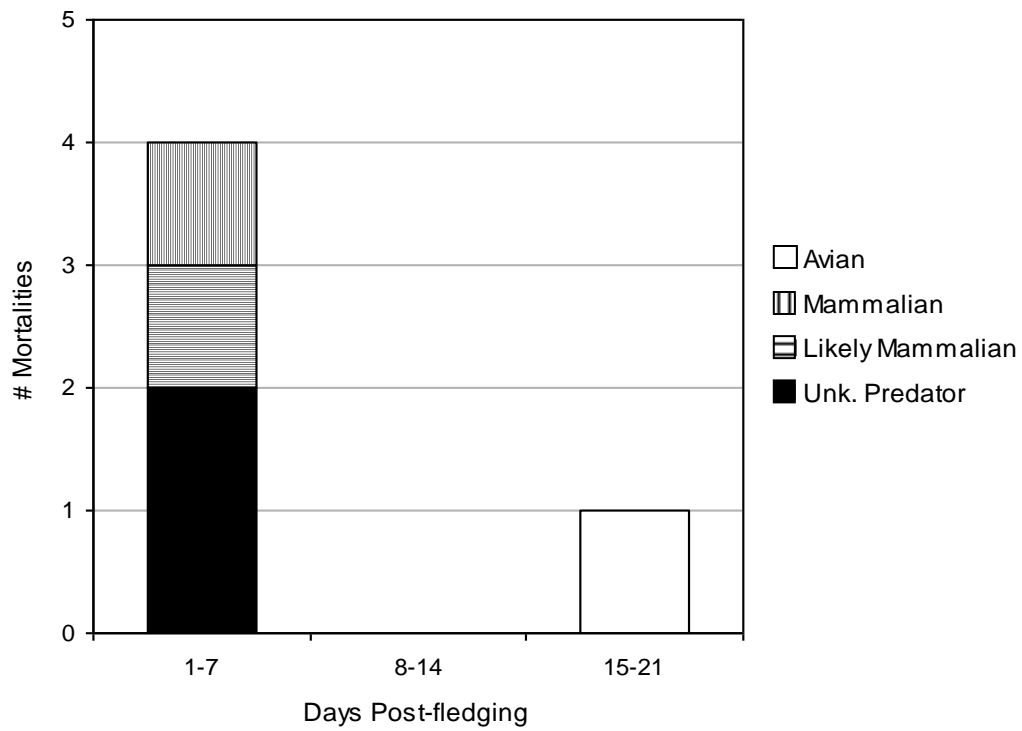


Figure 2.3. Causes of Acadian Flycatcher fledgling mortality ( $n = 5$ ) within survival time periods in central Ohio, 2008-2009.

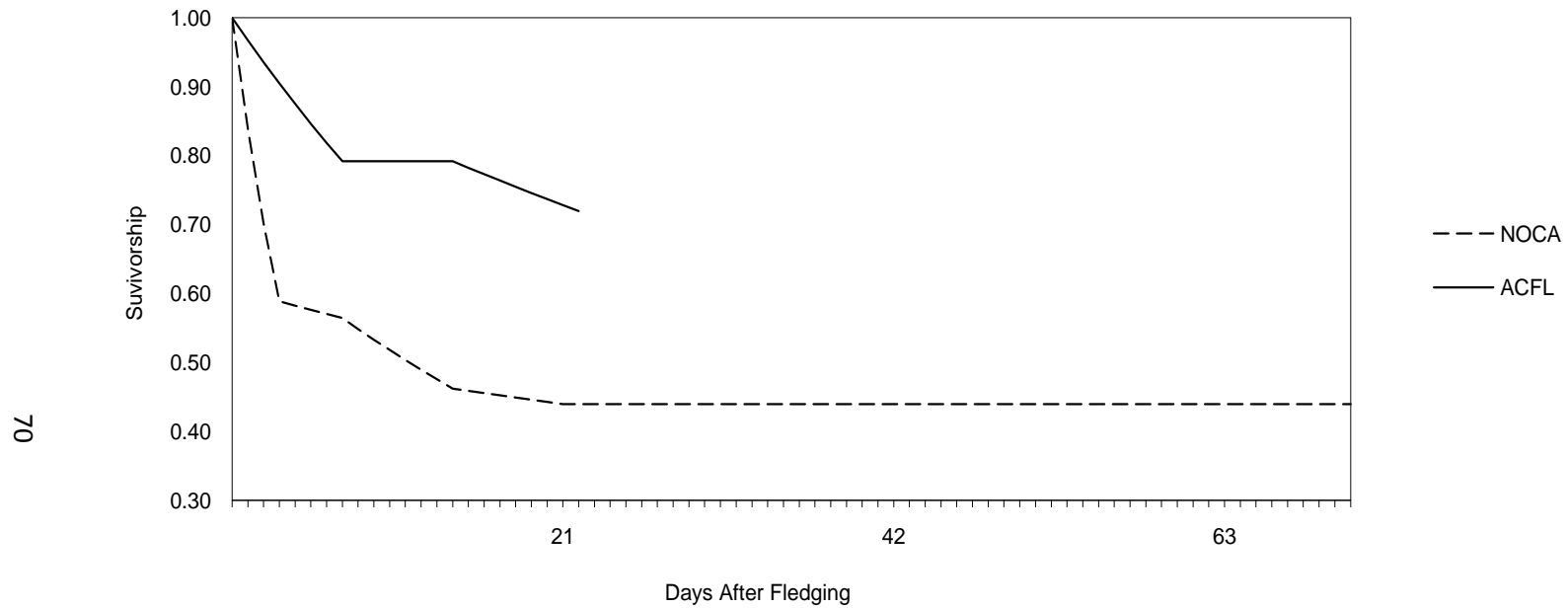


Figure 2.4. Cumulative survivorship using estimates from the top ranked time model for fledgling Northern Cardinals ( $n = 45$ ) and the second-ranked time model for Acadian Flycatchers ( $n = 31$ ) in central Ohio, 2008-2009.



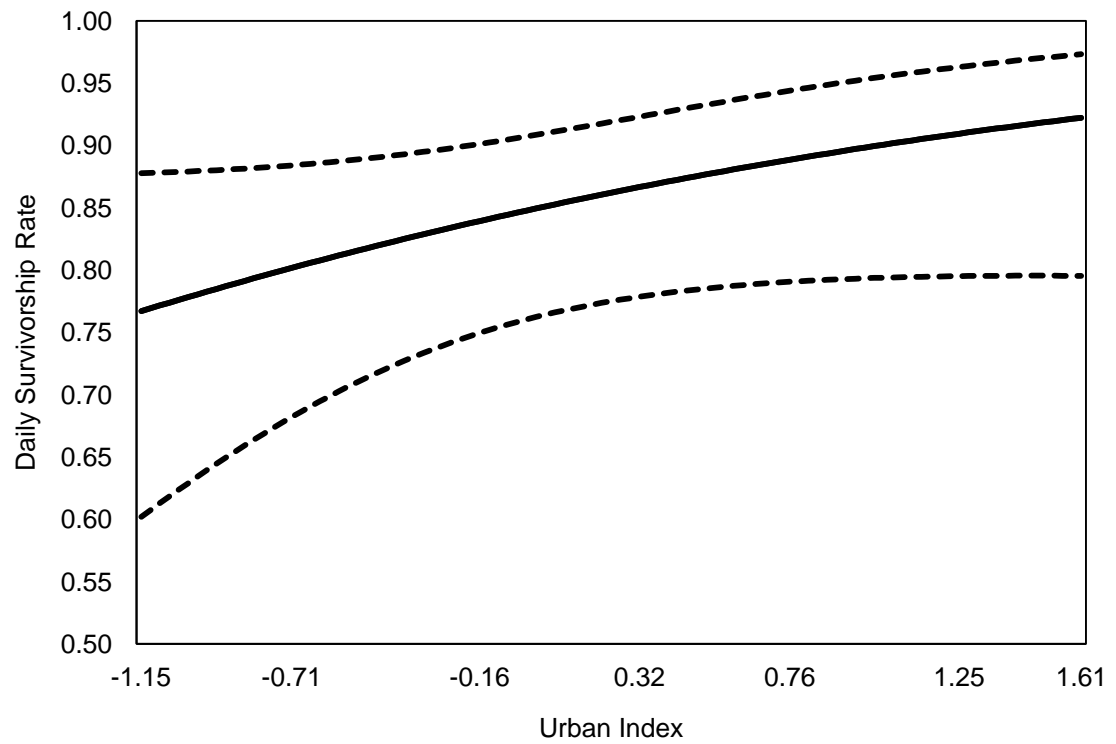


Figure. 2.5. Daily survivorship and 95% confidence interval for Northern Cardinal fledglings ( $n = 42$ ) during the first three days post-fledging in central Ohio, 2008-2009, in relation to the amount of urbanization in the surrounding landscape (Urban Index).

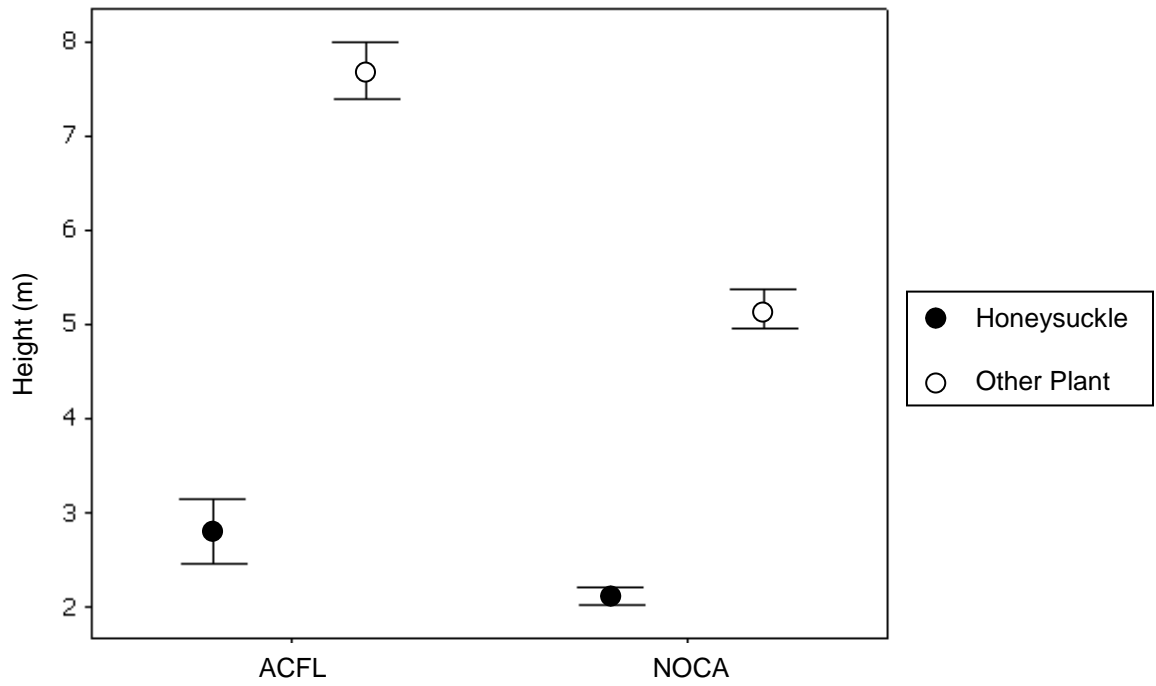
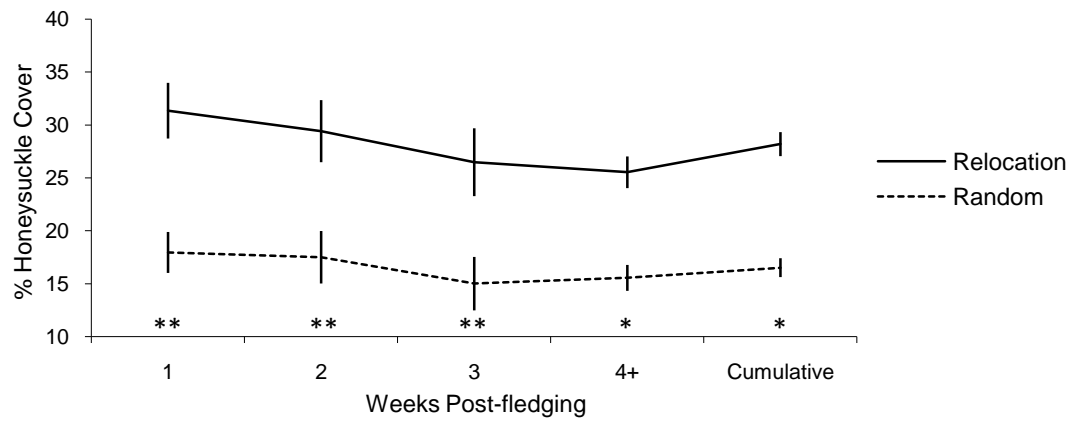
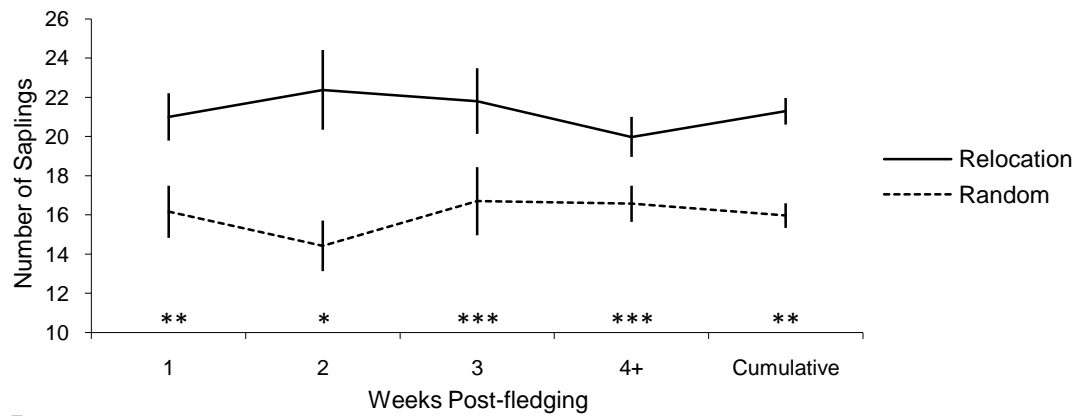


Figure 2.6. Average height of Acadian Flycatcher fledglings found in honeysuckle shrubs ( $n = 16$ ) and other substrates ( $n = 287$ ) and Northern Cardinal fledglings found in honeysuckle ( $n = 152$ ) and other substrates ( $n = 309$ ) in central Ohio, 2008-2009. Bars represent one standard error of the mean.



A



B

Figure 2.7. Average honeysuckle cover (A) and average number of saplings 3-8 cm DBH (B) at Northern Cardinal fledgling relocation sites ( $n = 473$ ) and random plots ( $n = 463$ ) by week post-fledging in central Ohio, 2008-2009. Bars represent standard error of the mean. Significance of univariate tests indicated by: \*  $P < 0.01$ , \*\*  $P < 0.05$ , \*\*\*  $P < 0.1$ .

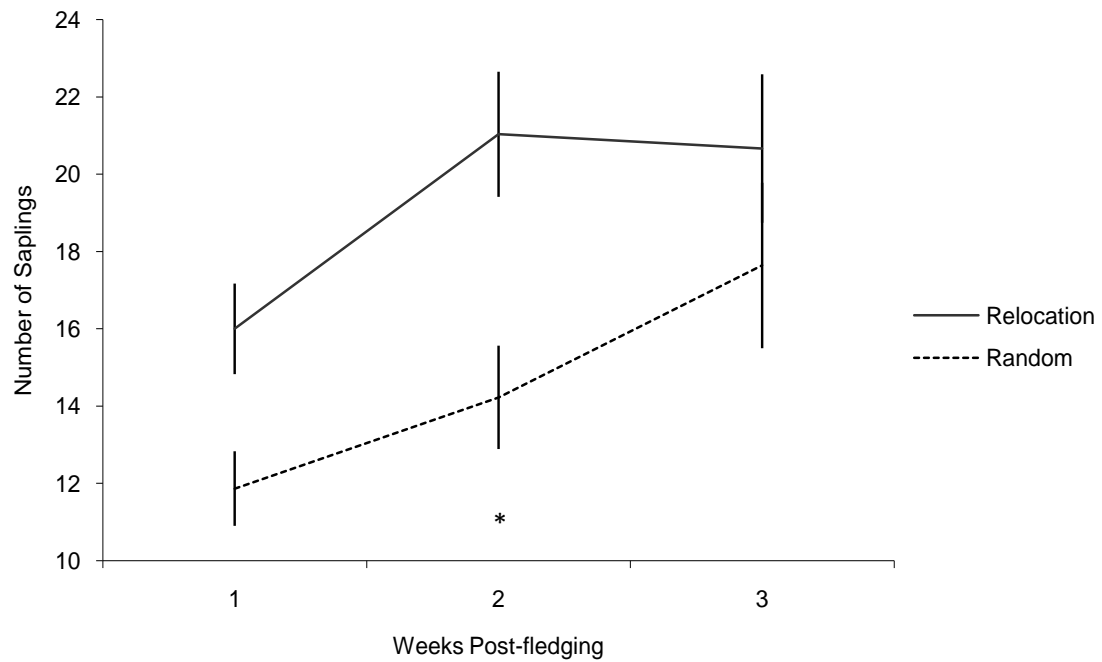


Figure 2.8. Average number of saplings 3-8 cm DBH at Acadian Flycatcher fledgling relocation sites ( $n = 352$ ) and random plots ( $n = 353$ ) by week post-fledging in central Ohio, 2008-2009. Bars represent one standard error of the mean. Significance of univariate tests indicated by \*  $P < 0.05$ .

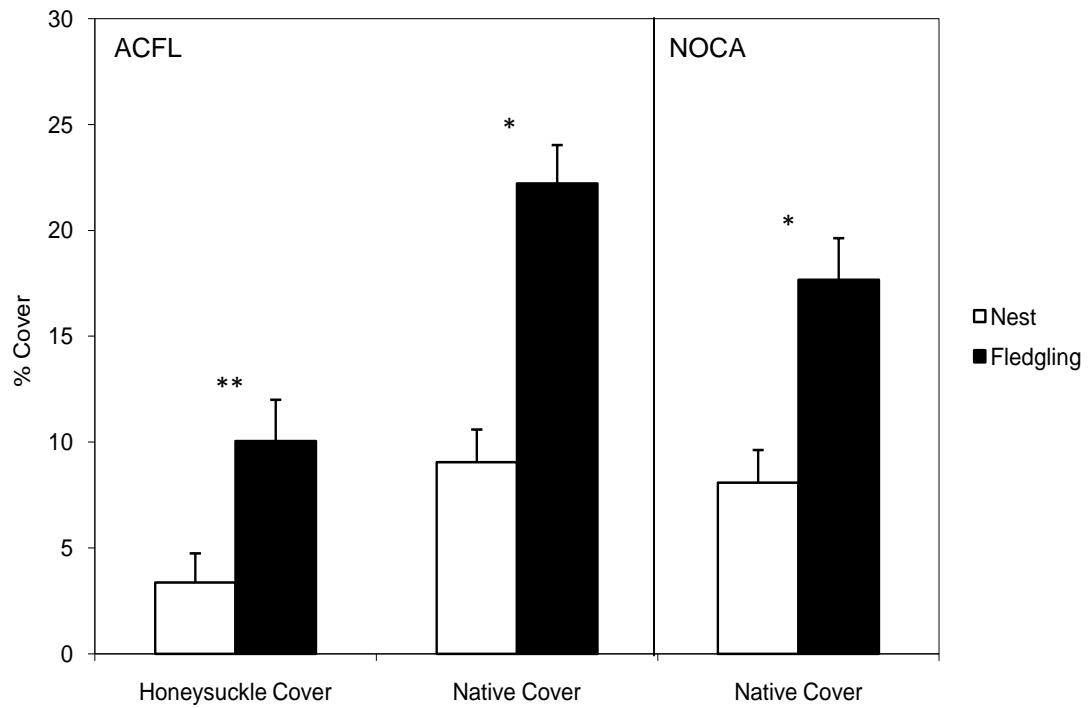


Figure 2.9. Average honeysuckle and native shrub cover at nest sites and fledgling relocations for Acadian Flycatchers ( $n = 28$ ) and Northern Cardinals ( $n = 29$ ). Bars represent standard error of the mean. Univariate  $F$ -statistics from discriminate function analysis are significant where: \*  $P < 0.001$ , \*\*  $P < 0.05$ .

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## CHAPTER 3

### POST-FLEDGING DISPERSAL TIMING AND NATAL HOME RANGE SIZE OF TWO SONGBIRD SPECIES

#### Abstract

Little is known about juvenile movements during the post-fledging stage of development. In particular, the ecological factors influencing natal home range size and the timing of post-fledging dispersal events remain relatively unexplored. During 2008 – 2009 breeding seasons I used radio telemetry to track movements of fledgling Northern Cardinals (*Cardinalis cardinalis*) ( $n = 45$ ) and Acadian Flycatchers (*Empidonax virescens*) ( $n = 31$ ) in a network of riparian forests embedded within an urbanizing landscape in central Ohio. A subset of 20 cardinals and 11 flycatchers survived sufficiently long for subsequent movement analyses. Cardinal natal home ranges ( $\pm$  SE) were less than half the size of those of flycatchers ( $0.93 \pm 0.13$  ha v.  $1.91 \pm 0.24$  ha) and were not related to condition at time of fledging, conspecific territory density at the natal site, fledging day, or preferred habitat features. Natal home range size of flycatchers was positively related to Amur honeysuckle (*Lonicera maackii*) cover and numbers of saplings and mature trees. During the study period, 70% of the cardinals dispersed from natal sites at an average of  $46 \pm 2$  days post-fledging. One flycatcher dispersed on day 21

post-fledging. Dispersal patterns of cardinals varied among individuals, with birds either dispersing locally within their natal forest fragments or making extended movements into the surrounding landscape matrix. Cardinals tended to disperse later from sites with high conspecific densities. Collectively, my results suggest that habitat features and conspecific interactions influence fledgling movements, but these patterns are not easily generalized across species.

## Introduction

Despite a growing literature regarding the survivorship and habitat use of juvenile birds (e.g. Anders et al. 1998, Rush and Stutchbury 2008, Vitz 2008), little is known about spatial ecology during the post-fledging stage of development. Fledgling movements can occur over a wide range of temporal and spatial scales (e.g., Anders et al. 1998, Vitz 2008, White et al. 2008), yet the ecological factors explaining such variation remain unclear. The post-fledging period represents a highly sensitive stage of the avian life cycle (Anders et al. 1997) that likely influences population viability (Anders et al. 2005). Thus, identifying factors that drive fledgling movements is important for managing appropriately sized and spatially configured reserves.

Daily movements early in the post-fledging period collectively delineate the natal home range, which is the area used prior to the initiation of post-fledging dispersal (Anders et al. 1998). Natal home range size may be associated with a variety of physiological, social, and environmental factors. For example, natal home range size increases with improved condition, likely because fledglings can move farther than weak

individuals (Naef-Daenzer and Gruebler 2008). Natal home ranges might also be inversely related to conspecific density due to resource competition, as demonstrated for adults (Haggerty 1998, but see Stober and Krementz 2006). On the other hand, because moving over large areas is energetically costly, home range size might decrease in areas with preferred microhabitat features (Springborn and Meyers 2005, Haggerty 1998, Garza et al. 2005, Stober and Krementz 2006, Whitaker et al. 2007) or rich food resources (Rolstad et al. 1995).

Post-fledging dispersal is the initial movement juveniles make when departing the natal area for future breeding territories (ie. natal dispersal; Greenwood and Harvey 1982) (Belthoff and Richison 1989, Anders et al. 1998, Cohen and Lindell 2004, Lang et al. 2002, Suedkamp Wells et al. 2008, Vitz 2008) and can occur as early as 13 days after leaving the nest for small passerines (Nilsson 1985) and as late as day 137 for large raptors (Ferrer 1993). Post-fledging dispersal generally coincides with the transition to independence when juveniles are no longer behaviorally dependent upon adults (Rivera et al. 1998, White et al. 2008). Upon dispersal fledglings make long linear movements to one or more areas of concentrated daily use, known as post-dispersal ranges (Anders et al. 1998). While the majority of studies have reported fledglings using just one post-dispersal area (Anders et al. 1998, Lang et al. 2002, Walls and Kenward 1997), as many as four distinct ranges have been recorded to occur within the first 9 weeks post-fledging (White et al. 2008).

Because natal dispersal is believed to improve an individual's ability to avoid inbreeding and competition for mates and environmental resources (Dobson and Jones

1985), a substantial literature has emerged regarding dispersal ecology (e.g., Clobert et al. 2001). Nevertheless, little is known about the ecological factors that influence the timing of the initial post-fledging dispersal movements. The ability of an individual to emigrate from its natal area has consequences for future immigration into breeding territories (Ims and Hjermann 2001). Larger individuals and those with improved condition disperse earlier (Nilsson and Smith 1985, Lens and Dhondt 1994, Ferrer 1992, but see Currie and Matthysen 1998, Middleton and Green 2008) likely because they are better able to meet the energetic costs of dispersing (Ims and Hjermann 2001) and claim preferred dispersal territories. Intraspecific competition at the natal site has also been positively associated with dispersal rates for a wide range of taxa (Lambin et al. 2001), though some studies suggest that dispersal is not density dependent for birds (Pasinelli and Walters 2002). Finally, habitat composition at the landscape scale can influence post-fledgling dispersal timing (Lens and Dhondt 1994). How microhabitat features influence dispersal timing is unknown.

I studied the spatial ecology of two species of songbirds, Northern Cardinal (*Cardinalis cardinalis*) and Acadian Flycatcher (*Empidonax virescens*), within an urbanizing landscape in central Ohio. I hypothesized that a suite of ecological factors would influence the timing of post-fledgling dispersal and natal home range extent. First, I predicted that natal home range size would be: 1) positively associated with individual condition at time of fledging, because birds with improved condition would be more mobile, 2) inversely related to conspecific territory density at the natal site, because adult home ranges would be subsequently smaller, and 3) inversely related to the extent of

preferred microhabitat features within the natal range, because fledglings would be less likely to move in areas that provide a perceived level of protective cover. Second, I predicted that dispersal timing for cardinals would be: 1) inversely related to condition at time of fledging, because birds in good condition can better meet the energetic costs associated with dispersal, 2) inversely related conspecific territory density at the natal site due to intraspecific competition for resources, 3) directly related to fledging date, because adults are more likely to reneest earlier in the breeding season and will have less time to care for previous broods, and 4) directly related to the amount of preferred microhabitat features, because fledglings will remain longer in natal ranges that provide a higher perceived amount of protective cover.

## Methods

*Study Area.* I conducted research in 26 mature riparian forests located along a rural-to-urban gradient in central Ohio (Franklin and Delaware Counties). Forests along the landscape gradient were of comparable size, shape, and spatial configuration and were > 2 km apart (Rodewald and Shustack 2008b). Common trees and woody understory plants included sycamore (*Plantanus occidentalis*), boxelder (*Acer negundo*), sugar maple (*A. saccharum*), black walnut (*Juglans nigra*), ash (*Fraxinus spp.*), American hackberry (*Celtis occidentalis*), Amur honeysuckle (*Lonicera maackii*), common spicebush (*Lindera benzoin*), tall pawpaw (*Asimina triloba*), and Ohio buckeye (*Aesculus octandra*).



*Study Species.* Northern Cardinals and Acadian Flycatchers were selected as study species for a parallel study regarding the effects of urbanization on fledgling survivorship (Chapter 2) and provided an opportunity to contrast the spatial ecology of two species with dramatically different life history strategies. Acadian Flycatchers are migratory, feed exclusively on arthropods, and generally breed in large, undisturbed tracts of mature forests (Whitehead and Taylor 2002). Cardinals do not migrate, feed on a variety of food resources, and are known to breed within a diverse assortment of disturbed and undisturbed habitats (Halkin and Linville 1999). Previous research within the study system indicates that cardinals respond positively, and flycatchers negatively, to urbanization within the surrounding landscape matrix (Rodewald and Bakermans 2006).

*Field.* I used radio telemetry to track the movements of cardinal and flycatcher fledglings in May – July 2008 and 2009. Cardinal nests were sampled in accordance with criteria developed for a parallel project studying the effects of urbanization on fledgling survivorship. Nests were prioritized based on the need to track birds across the entire rural-to-urban landscape gradient (Chapter 2). All accessible flycatcher nests were sampled. Nests were monitored every 2-3 days for cardinals and 3-4 days for flycatchers until four days before the expected time of fledging, whereupon nests were monitored daily. Because cardinal fledglings have been observed to fledge as early as Day 10 post-hatching in my system, I tagged most nestlings at age Day 7-8, with the exception of two birds estimated to be 9-10 days old. For Acadian Flycatchers, nestlings were tagged on the day before or on their expected fledgling date, which usually was Day 13-14. Nearly all flycatchers left the nest within two hours after tagging. Therefore, I attempted to tag

nestlings at the latest date possible before fledging when I estimated that they had maximally developed. Over both years I was able to track fledglings in 16 of my original forest sites.

I used a modified figure-8 harness made of a cotton-nylon elastic blend to attach transmitters (Rappole and Tipton 1991). To avoid issues surrounding lack of independence I randomly selected one nestling of sufficient mass within each nest for tagging. Cardinal tags weighed on average 5.8% of the fledgling's mass (tag mass: 1.45g, BD-2, Holohil Systems Ltd.) and had a battery life of 9 weeks ( $n = 20$ ) and 5 weeks ( $n = 1$ ). Flycatcher tags weighed on average 4.8% of each fledgling's body mass and had a battery life of 16-21 days (tag mass: 0.47g and 0.6g, BD-2N, Holohil Systems Ltd.). Transmitters are widely used to assess animal movements (eg., Marzluff and Millsaugh 2001, Kenward 2001) and have been shown to have little impact on individual condition (Rae 2009) or behavior (Naef-Daenzer 1993). In addition, two cardinals were resighted without their transmitters a year following tagging, indicating that they had successfully dropped their tags.

All nestlings from each nest received one numeric USGS aluminum band and three colored plastic bands. Immediately after removal from the nest, I weighed each nestling with a Pesola spring scale (0.05g accuracy) and measured the length of the right tarsus using standard procedures (Pyle 1997). Processing time from the point of removing the first nestling to the replacement of the last nestling varied between 15 and 60 minutes depending on the number of nestlings.

During relocation events every 1-2 days, I visually confirmed the identity of tagged fledglings through radio telemetry homing techniques and by resighting color bands. At each relocation point I recorded coordinates using WAAS-enabled Garmin 12 XL and DeLorme pn-40 GPS units ( $\pm 6.5$  m average error). I only recorded coordinates when I had determined the individual's precise location, either through visual detection or change in transmitter signal.

I estimated percent honeysuckle and native shrub cover and counted the number of saplings (3-8 cm DBH) and mature trees ( $> 8$  cm DBH) at relocation points daily for flycatchers and every 2-3 days for cardinals due to time constraints. I surveyed vegetation only at points where the bird was visually located. Vegetation was assessed using a modified version of the James and Shugart (1970) method within 0.04-ha circles centered at the relocation point.

Cardinal territory density was estimated from spot-map surveys (Bibby et al. 2000) conducted within one 2-ha grid at each site. Ten weekly surveys were completed from May through July in 2008 and 2009 and were designed to detect every cardinal within the grid. Fledgling condition was estimated from the residuals of a regression of tarsus length on body mass. Negative and positive residuals, respectively, represent poorer and better condition compared to that predicted for an individual of a given frame size.

Because I was working within forest stands surrounded by a landscape matrix ranging from predominately rural to entirely urban, I included an index of urbanization in my analysis of factors influencing fledgling movements. Landscape composition within a

1-kilometer radius circle surrounding each forest was quantified by analyzing digital orthophotos (2002-04) and building data from Franklin and Delaware Counties. Other studies have shown strong associations between bird communities and this 1-kilometer scale (Tewksbury et al. 1998, Saab 1999, Rodewald and Yahner 2001, Rodewald and Bakermans 2006). The first principal component of a principal components analysis examining developed features explained 80% of the variation among sites (eigenvalue = 3.99) (Rodewald and Shustack 2008b). Factor 1, referred to here as the “urban index”, loaded positively for number of buildings (0.92), percent road cover (0.94), pavement (0.90), and lawn (0.88), but loaded negatively for percent agricultural cover (-0.83) (Rodewald and Shustack 2008b). The urban index was not correlated with forest width, thereby avoiding any confounding between habitat area and urbanization (Rodewald and Shustack 2008b).

*Home Range Analysis.* I constructed natal home ranges using minimum convex polygons (MCPs) and kernel density estimation (KDE). Natal home ranges for flycatchers were calculated using MCPs since sample sizes were too small for KDE ( $n < 30$ ) (Kernohan et al. 2001). Because MCPs are sensitive to outliers (Kernohan et al. 2001), I calculated 95% MCPs using the “Area Added” function within the Home Range Extension for ArcGIS (Rodgers and Carr 2002a). This function removes points that contribute the largest amount of area to the MCP until the requested percentage of points is reached (Rodgers and Carr 2002b).

I calculated cardinal natal home ranges using both 95% MCPs and KDEs to facilitate comparison with studies using both methods. MCPs have been criticized for

producing spurious results due to inconsistent recognition of assumptions and are considered less accurate than kernel density estimators (KDEs) (Laver and Kelly 2008, but see Wauters et al. 2007). I used the likelihood cross-validation (CVh) rather than the least squares cross-validation (LSCVh) smoothing method to construct fixed kernel density estimations because LSCV can undersmooth data consisting of small sample sizes ( $n < 50$ ) (Horne and Garton 2006). For fledglings that dispersed from the natal area, the natal home range was defined by all relocation points collected prior to the dispersal event. Ninety-five percent MCPs were constructed to identify outlying points, which were then deleted from the final dataset used to construct natal KDEs. The CVh smoothing factor for each individual was then calculated using the program Animal Space Use 1.3 (Horne and Garton 2009). Ninety-five percent and 50% fixed kernel density estimations were calculated in the Home Range Extension for ArcGIS (Rodgers and Carr 2002a) by manually entering the CVh smoothing factor as a user defined value. Interval analysis for MCPs using the ArcView Animal Movement Extension v. 2 (Hooge and Eichenlaub 1997) indicated that neither cardinal nor flycatcher natal ranges reached an asymptote, which was likely due to limited sample sizes and the fact that fledgling birds are developing behaviorally and expand their natal ranges as their flight capabilities improve. However, 95% MCP, 95% KDE and 50% KDE home ranges for cardinals were highly correlated (95% MCP v. 95% KDE:  $r = 0.955$ ,  $P < 0.001$ ; 95% MCP v. 50% KDE:  $r = 0.923$ ,  $P < 0.001$ ; 95% KDE v. 50% KDE:  $r = 0.956$ ,  $P < 0.001$ ), indicating that MCP estimates were likely accurate. To examine the role sample size played in influencing flycatcher home range size, I estimated 95% MCPs for individuals at Day 17 post-fledging when sample sizes were equal across individuals. The two home range

estimates were strongly correlated ( $r = 0.981$ ,  $P < 0.0001$ ), whereas sample size was not correlated with 95% MCP size at Day 17 ( $r = -0.157$ ,  $P = 0.644$ ) or at the final detection age ( $r = -0.081$ ,  $P = 0.813$ ). Hence, 95% MCP estimates at the final detection age were considered to be the most suitable estimate to use in subsequent analyses.

*Dispersal Analysis.* Past studies have identified post-fledging dispersal timing by either qualitatively describing sudden large movements (Anders et al. 1998, White et al. 2008) or by selecting a threshold movement value upon which birds are considered dispersed (Vitz 2008, King and Belthoff 2001). Qualitative assessments are sufficient when individuals make obvious large movements from the natal area, but subtle shifts in area used may not be noticeable. Likewise, imposing a threshold value common to all individuals may obscure individual variation in dispersal behavior.

I first assessed juvenile movements qualitatively by visually identifying single or sequential movements of relatively long length. A bird was considered dispersed if it left the natal area and never returned (Anders et al. 1998, White et al. 2008, Belthoff and Richison 1989). I then quantitatively assessed dispersal movements through segmented regression analyses of distance from nest and density of relocation points on days post-fledging using the program SegReg (Oosterban 2002). SegReg fits a set of predefined trend lines with breakpoints and selects the trend that maximizes the coefficient of explanation  $E$ . When the trend is linear without a breakpoint,  $E$  is equivalent to the correlation coefficient  $R^2$ . With segmented regression  $E$  becomes a better measure of explained variation because it takes into account the estimated breakpoint. A segmented trend is considered a better fit than a linear trend when  $E$  exceeds the value of  $R^2$  and is

proven to be a significantly better estimation of explained variation using goodness of fit *F*-tests (Oosterban 2005, Oosterban 2008). I used distance from nest and density of relocation points as dependent variables, because my observations in the field suggested that fledglings moved farther from the nest and used a larger area with age. Density of relocation points was calculated by creating 95% fixed kernel density estimations for the entire post-fledging range of each bird. The qualitative and quantitative methods determined the same dispersal dates within 1 – 2 days for 19/21 birds. The segmented regression analysis calculated a premature breakpoint for one of the remaining birds and failed to detect a breakpoint for the second. Because the dispersal patterns of these two birds seemed visually obvious, I relied upon the qualitative method to determine dispersal timing.

I calculated distances between natal and dispersal areas using the Spider Diagram tool in the ArcView Animal Movement Extension v. 2 (Hooge and Eichenlaub 1997). From the center of each natal home range I calculated the distance to each dispersal point and then averaged all distances per distinct dispersal area to arrive at an average dispersal distance. Areas where juveniles spent at least three days after dispersing were considered distinct dispersal areas (White et al. 2008). Dispersal timing for flycatchers was not calculated due to limited transmitter battery life.

*Analysis of Ecological Factors.* When examining the associations between natal home range size, dispersal timing and a suite of ecological factors, I used an information-theoretic framework that compares relative weight of evidence for multiple models using Akaike's Information Criteria (AIC<sub>c</sub>) corrected for small sample sizes (Burnham and

Anderson 1998). The model with lowest  $AIC_c$  value was considered best, and competing models ( $<2 \Delta AIC_c$  from the top model) were considered equally plausible given the data. Akaike weights ( $\omega_i$ , weight of evidence for each model) indicated the relative support for each model and represented the likelihood that any given model was the true best model. Variables were square-root or log transformed to meet assumptions of normality.  $AIC_c$  values were derived from linear models constructed with PROC GENMOD (SAS Institute 2003) assuming a normal distribution and employing the identity link function.

## Results

I tagged a total of 45 fledgling cardinals (24 in 2008 and 21 in 2009) and 31 fledgling flycatchers (13 in 2008 and 18 in 2009). High mortality rates and malfunctioning transmitters reduced the sample size of individuals tracked to independence to 21 cardinals and 11 flycatchers. Cardinals and flycatchers were tracked 42 – 71 days and 18 – 22 days post-fledging, respectively, depending on transmitter life, dispersal movements and logistical constraints (Table 3.1). One cardinal dropped its tag prematurely at Day 40 post-fledging and was censored from subsequent analyses.

Average natal home range ( $\pm$  SE) for cardinals using 95% MCP estimation and 95% KDE was  $0.93 \pm 0.13$  ha (range: 0.18 – 2.7 ha) and  $1.55 \pm 0.21$  ha (range: 0.37 – 4.4 ha), respectively. Average core natal home range (50% KDE) was  $0.34 \pm 0.05$  (range: 0.09 – 1.10 ha). Flycatcher home ranges (95% MCP) were on average 2 times larger than those of cardinals ( $1.91 \pm 0.24$  ha).



Variation in home range size of cardinals was not well explained by any explanatory variables considered in my analysis, as the null model was included in the top model set and 95% confidence intervals of parameter estimates included zero (Table 3.2a). In contrast, home range size of flycatchers was best explained by and positively related to number of mature trees (>8 cm DBH), which held a weight of evidence of 0.938. Though not included in the top model sets, 95% confidence intervals suggested that home ranges of flycatchers also increased with increasing abundance of mature trees, saplings (3-8 cm DBH), and honeysuckle cover (Table 3.2b; Fig. 3.1).

I detected post-fledging dispersal movements for 14 of 20 (70%) cardinals (Table 3.3). Of the remaining six individuals, three made extended dispersal-like movements upon reaching a specific age post-fledging but then returned frequently to the natal range. Fledglings dispersed from the natal area an average ( $\pm$  SE) of 46 days  $\pm$  2 days post-fledging in either local or extended movements. Birds that dispersed locally did so within their natal forest fragment ( $n = 7$ ; Fig. 3.2), whereas birds making extended movements set up dispersal territories in new forest fragments or within the surrounding landscape matrix ( $n = 6$ ; Fig. 3.3). Dispersal distance for birds making extended movements (median = 594 m) was significantly larger than for birds dispersing locally (median = 171 m;  $U = 58.0$ ,  $P = 0.0268$ ). Of the birds that dispersed, 11 moved to a single dispersal area, one moved to two, and one moved to three. The remaining individual is assumed to have dispersed out of the range of the telemetry receiver, because its signal disappeared 2.5 weeks before expected battery failure. Six of the fledglings that dispersed made exploratory movements into their future dispersal area prior to dispersing. Five birds

made one movement (3, 5, 10, 11, and 12 days before dispersing) and one made two movements 3 and 4 days prior to dispersal. Of the birds that had dispersed prior to transmitter failure, the model including conspecific territory density best explained variation in dispersal date, holding a weight of 0.990 (Table 3.4; Fig. 3.4).

## Discussion

Habitat structure and intraspecific social cues influenced natal home range size and dispersal timing, though explanatory variables differed for each species. Flycatchers expanded their natal home ranges as the extent of honeysuckle and abundance of saplings and mature trees increased. Cardinals dispersed later from natal sites where conspecific territory densities were higher.

My estimates of natal home range size for cardinals and flycatchers are 5 to 10 times and 2.5 to 5 times smaller, respectively, than those reported for several mature-forest species, including Wood Thrush (*Hylocichla mustelina*; 4.46 – 9.5 ha; Anders et al. 1998), Worm-eating Warbler (*Helmitheros vermivorus*; 10.6 ha; Vitz and Rodewald 2010), and Ovenbird (*Seiurus aurocapillus*; 5.02 ha; Vitz and Rodewald 2010). The natal ranges of Gray Catbirds (*Dumetella carolinensis*) within an urban landscape were similar in size (1.7 ha; Balogh and Marra unpublished data) to those reported in my study.

Variation in territory size for birds has been attributed to physiological (Naef-Daenzer and Gruebler 2008), social (Silllett et al. 2004, Pons et al. 2008), and habitat factors (e.g., Smith and Shugart 1987). Territory size is often reported to vary inversely

with food availability (McLoughlin and Ferguson 2000, Rolstad et al. 1995, but see Franzblau and Collins 1980), and habitat features can indicate present or future food resources (Smith and Shugart 1987, Marshall and Cooper 2004, Stober and Krementz 2006). Because natal range size for flycatchers was directly rather than inversely related to vegetative cover, fledglings may have perceived habitat quality as a function of food availability rather than extent of protective cover. This scenario is consistent with previous work in my study system that demonstrated strong preferences by flycatchers to nest in areas with open understory and abundant arthropods (Bakermans and Rodewald 2006). Habitat apparently did not influence food availability for cardinals given that natal range size was not associated with any particular structural feature.

Because fledglings are behaviorally dependent upon their parents before reaching independence, their movements are likely influenced by parental behavior as well. Adults will frequently move their broods beyond exclusive breeding territories (White et al. 2008, Matthysen et al. 2010) and subsequently influence where (Matthysen et al. 2010) and when (White et al. 2008) fledglings disperse. Limited evidence suggests that the mobility of fledglings from “stationary” and “drifting” broods is similar (White et al. 2008) but more research is needed to explicitly test the assumption that parental behavior influences fledging space use.

Cardinals initiated post-fledging dispersal movements 2 to 3.5 weeks later than other species including Wood Thrush (22.3 – 32.5 days post-fledging; Anders et al. 1998, Rivera et al. 1998, Lang et al. 2002), Gray Catbird (23.8 days; Balogh and Marra unpublished data), White-throated Robin (*Turdus assimilis*; 31.1 days; Cohen and Lindell

2004), Worm-eating Warbler (21.8 days; Vitz and Rodewald 2010), and Ovenbird (29.2 days; Vitz and Rodewald 2010). While transmitter battery life limited my ability to detect flycatcher dispersal events, one individual dispersed 1 km south of its natal area 21 days post-fledging. Other studies also report dispersal movements 3-4 weeks after fledging for flycatchers (Whitehead and Taylor 2002).

Cardinals likely dispersed later than flycatchers because they do not face energetic and temporal constraints associated with migration. Whereas flycatchers migrate several thousand kilometers annually, juvenile cardinals generally move no more than 100 kilometers away from their natal ranges, and many individuals remain within a few kilometers of their nest site (Halkin and Linville 1999). This pattern holds true across avian taxa, with migratory species making comparatively large natal and breeding dispersal movements (Paradis et al. 1998, Sutherland et al. 2000).

I observed variation in post-fledging dispersal movements for cardinals within and beyond the natal range. Individuals either dispersed abruptly to novel locations within the surrounding landscape matrix or moved gradually to areas proximate to their natal ranges. Of the birds that dispersed gradually, several made exploratory excursions into their future dispersal ranges long before dispersing permanently from the natal range. Since data from spot map surveys (Rodewald et al. unpublished data) indicate that these individuals dispersed from natal ranges and into neighboring territories, such exploratory movements suggest that boundaries between natal and dispersal ranges may remain “soft” for some individuals. Additionally, two males were philopatric and were observed attempting to establish territories the following year within their natal forest stands.

The pattern of delayed cardinal dispersal with increasing conspecific territory density might result if fledglings and territorial individuals both responded to high levels of resources at sites. In my study system breeding densities of cardinals matched resource levels such that individual fitness was comparable across sites with varying densities (Rodewald and Shustack 2008a). Hence, fledglings at high-density sites may have had similar resources to those at low-density sites. Fledglings may have also used population density as a social cue indicating the quality of habitats (Forsman et al. 2009).

Despite observing dispersal movements for the majority of cardinal individuals, my data are limited by three important caveats. First, my analysis is restricted to those individuals that dispersed within the lifespan of their transmitters. Because I failed to resight all but two tagged fledglings during subsequent breeding seasons, stationary individuals likely dispersed after my study concluded. Second, I was unable to collect systematic behavioral observations during relocation events and, therefore, confirm that fledglings disperse upon achieving independence. Given that some individuals can reach independence prior to dispersing (White et al. 2008), my natal ranges may not have been exclusively used by dependent fledglings. Finally, dispersal distances can vary dramatically between sexes, and I was unable to determine the sex of cardinal fledglings in the field.

To the best of my knowledge this is the first attempt at using segmented regression analysis (SRA) to quantify animal dispersal movements. While abrupt movements were easily detected, the analysis also successfully estimated when individuals made gradual movements to dispersal territories proximate with the natal

range. Those employing this technique, however, should have an intimate knowledge of their subjects' movement patterns, especially when selecting the dependent regression variable. For example, using distance from nest as the dependent variable might not be successful for species exhibiting "wandering" natal movements (Anders et al. 1998, White et al. 2008), because the SRA might identify breakpoints between centers of activity prior to the true dispersal movement. In my study, corroboration of SRA on two dependent variables in addition to qualitative assessments was required to successfully identify timing of dispersal for 85% of the dispersed individuals. The fact that the SRA failed for two individuals indicates that qualitative methods used historically to identify dispersal dates (e.g., White et al. 2008) should still be used in concert with quantitative methods.

This study adds to the conceptual and methodological body of knowledge on post-fledging ecology. Although habitat structure and social cues were associated with specific movement parameters for cardinals and flycatchers, no single ecological factor consistently explained variation in dispersal timing or natal home size between species. Future research is needed to understand how life history traits and natural history shape the movement ecology and dispersal behavior of post-fledging birds.

Bird	Site	Days Post-fledging at Last Detection	N	Fledging Day (Julian)	Year
30	Casto	71	46	129	2009
151	Lou	69	53	133	2009
191	Crees	57	46	135	2009
340	Rushrn	59	55	153	2008
379	Tuttle	48	37	206	2008
390	Woodside	42	34	213	2008
440	Rushrn	59	42	153	2008
471	Prairie	55	46	157	2008
472	Prairie	57	48	143	2009
510	Lou	56	42	146	2009
559	Lou	64	52	181	2008
590	Sgalena	54	45	153	2009
600	Tuttle	56	46	190	2008
620	Lou	46	37	208	2008
647	Cherry	62	49	156	2009
671	Pubhunt	63	57	193	2008
730	Sgalena	55	45	157	2009
790	Elkrun	60	49	166	2009
829	Sgalena	67	57	175	2009
850	Kenny	62	46	191	2009

A

Bird	Site	Days Post-fledging at Last Detection	N	Fledging Day (Julian)	Year
477	Tnc	22	22	180	2009
478	Tnc	21	21	221	2008
518	Bigwalnut	22	22	180	2009
538	Creeks	20	20	182	2009
658	Bigwalnut	20	20	201	2009
699	Smith	19	19	207	2009
718	Tuttle	18	17	208	2009
739	Casto	22	22	213	2009
759	Woodside	22	22	213	2009
839	Galena	18	18	220	2009
859	Sunbury	19	19	224	2009

B

Table 3.1. Sampling distribution of radio-tagged Northern Cardinal (A:  $n = 20$ ) and Acadian Flycatcher (B:  $n = 11$ ) fledglings and relocation points in central Ohio 2008 – 2009.  $n$  equals the number of relocation points for each individual

	AICc	$\Delta$ AICc	$\omega_i$	k	Beta	SE	95% CI
Condition	36.088	0.000	0.290	2	0.093	0.052	-0.009 - 0.195
Null	36.234	0.146	0.269	1	-	-	-
Honeysuckle Cover	37.591	1.503	0.137	2	-0.667	0.546	-1.737 - 0.403
NOCA Territory Density	38.205	2.117	0.101	2	0.323	0.352	-0.367 - 1.013
Sapling Density	38.922	2.834	0.070	2	0.050	0.154	-0.252 - 0.352
Native Shrub Cover	39.028	2.940	0.067	2	0.003	0.249	-0.485 - 0.492
Urban Index	39.028	2.940	0.067	2	-0.001	0.124	-0.243 - 0.241

A

	AICc	$\Delta$ AICc	$\omega_i$	k	Beta	SE	95% CI
Mature Tree Density	201.279	0.000	0.938	2	781.386	198.663	392.014 – 1170.759
Honeysuckle Cover	207.487	6.208	0.042	2	3412.896	870.159	1707.417 – 5118.376
Sapling Density	209.011	7.732	0.020	2	3905.393	1264.581	1426.859 – 6383.926
Null	233.611	32.332	0.000	1	-	-	-
Urban Index	235.669	34.390	0.000	2	3296.564	2308.123	-1227.280 – 7820.400
Condition	237.419	36.140	0.000	2	2457.799	7038.784	-11338 – 16253.56

B

Table 3.2. Models of ecological factors explaining variation in Northern Cardinal core natal home ranges (A) (50% KDE;  $n = 20$ ) and Acadian Flycatcher natal home ranges (B) (95% MCP;  $n = 10$ ) in central Ohio, 2008-2009. Condition represents energetic condition of fledglings at time of tagging, adult territory density represents the density of cardinal breeding territories within the natal site, honeysuckle cover represents average percent cover of honeysuckle shrubs at relocation plots, and sapling density and mature tree density represent the number of trees 3-8 cm DBH and  $> 8$  cm DBH at relocation plots. The betas estimate the strength of the individual models.



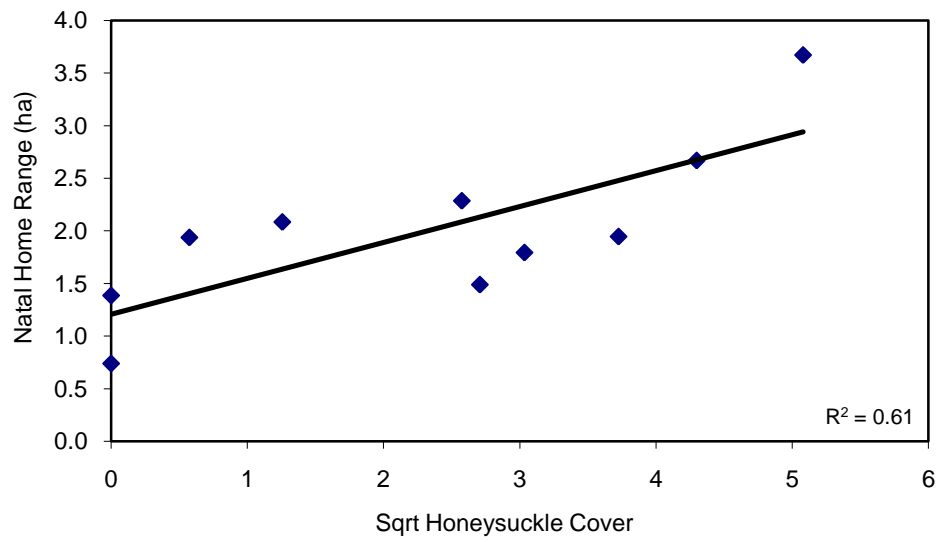
Table 3.3. Criteria for determining post-fledging dispersal timing for Northern Cardinals ( $n = 20$ ) exhibiting three different dispersal behaviors within the study time period in central Ohio 2008-2009. The coefficient of explanation  $E$  describes the amount of variation explained by the segmented model and is similar to the correlation coefficient  $R^2$ . Final Date Criteria were based on qualitative visual estimates from relocation points (V) and segmented regression analysis of distance from nest (N) and density of relocation points (D).

Bird	Visual Estimate of Dispersal (Days)	Distance from Nest		Density of Relocation Points		Final Dispersal Date	Final Date Criteria
		Breakpoint (Days)	<i>E</i>	Breakpoint (Days)	<i>E</i>		
<i>Dispersed</i>							
30	54-56	45.8	0.795	54.2	0.469	55	V, D
151	51-52	51.3	0.677	-	0.511	52	V, N
191	43-44	43	0.957	41.3	0.598	44	V, N
340	53-54	48	0.877	-	0.694	54	V
390	34-35	34.2	0.470	22.7	0.397	35	V, N
440	35-36	35.2	0.992	34.1	0.644	36	V, N
471	37-38	23.1	0.658	-	0.014	38	V
472	43-46	45.1	0.858	41.3	0.711	46	V, N
510	33-35	-	0.699	35.7	0.616	35	V, D
620	42	35.2	0.158	-	0.001	-	*
647	46-47	45.5	0.929	41.3	0.713	47	V, N
671	45-46	45	0.741	25.2	0.414	46	V, N
730	41-42	41.5	0.909	24.2	0.542	42	V, N
850	49-50	48.6	0.603	24.2	0.532	50	V, N
<i>No dispersal - extended movements after the breakpoint with frequent returns to the natal range</i>							
559	37-39	37.5	0.339	36.3	0.47	39	V, N
600	46-47	45.2	0.262	37.4	0.276	47	V, N
829	50-51	54.5	0.351	49.2	0.272	51	V, D
<i>No dispersal or changes in the magnitude of movements</i>							
379	-	39.1	0.188	-	0.026	-	-
590	-	10	0.269	-	0.008	-	-
790	-	-	0.389	-	0.573	-	-

Table 3.3

	AICc	$\Delta$ AICc	$\omega_i$	k	Beta	SE	95% CI
NOCA Territory Density	86.214	0	0.989	2	15.892	5.064	5.966 - 25.816
Null	97.532	11.318	0.003	1	-	-	-
Fledging Day	97.572	11.358	0.003	2	-0.117	0.061	-0.236 - 0.002
Condition	99.238	13.024	0.001	2	1.196	0.918	-0.602 - 2.994
Urban Index	99.845	13.631	0.001	2	1.821	1.791	-1.689 - 5.330
Sapling Density	100.297	14.083	0.001	2	1.510	2.026	-2.461 - 5.480
Honeysuckle Cover	100.343	14.129	0.001	2	-5.972	8.382	-22.401 - 10.457

Table 3.4. Models of ecological factors explaining variation in Northern Cardinal post-fledging dispersal timing in central Ohio, 2008-2009. Condition represents energetic condition of fledglings at time of tagging, adult territory density represents the density of cardinal breeding territories within the natal site, honeysuckle cover represents average percent cover of honeysuckle shrubs at relocation plots, and sapling density represents number of stems 3-8 cm DBH at relocation plots. The betas estimate the strength of the individual models.

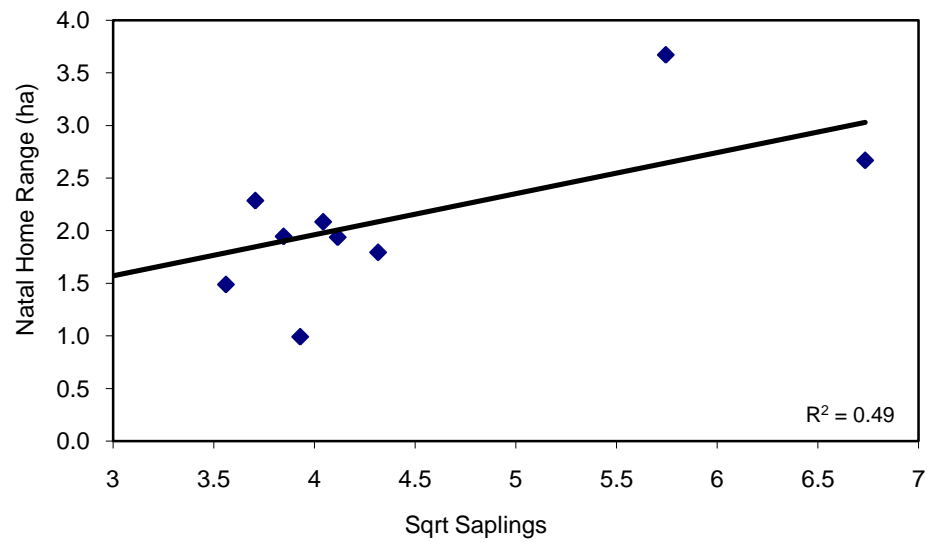


A

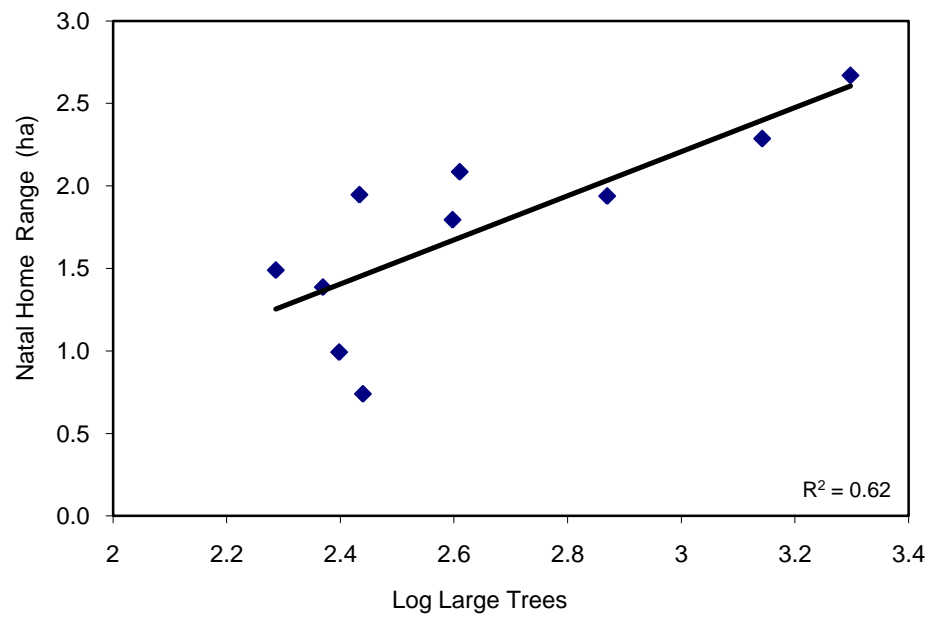
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Figure 3.1. Association between Acadian Flycatcher natal home range size (95% MCP) and honeysuckle cover (A), sapling density (B), and mature tree density (C) at relocation plots in central Ohio 2008-2009.  $n = 10$ .

Figure 3.1 continued

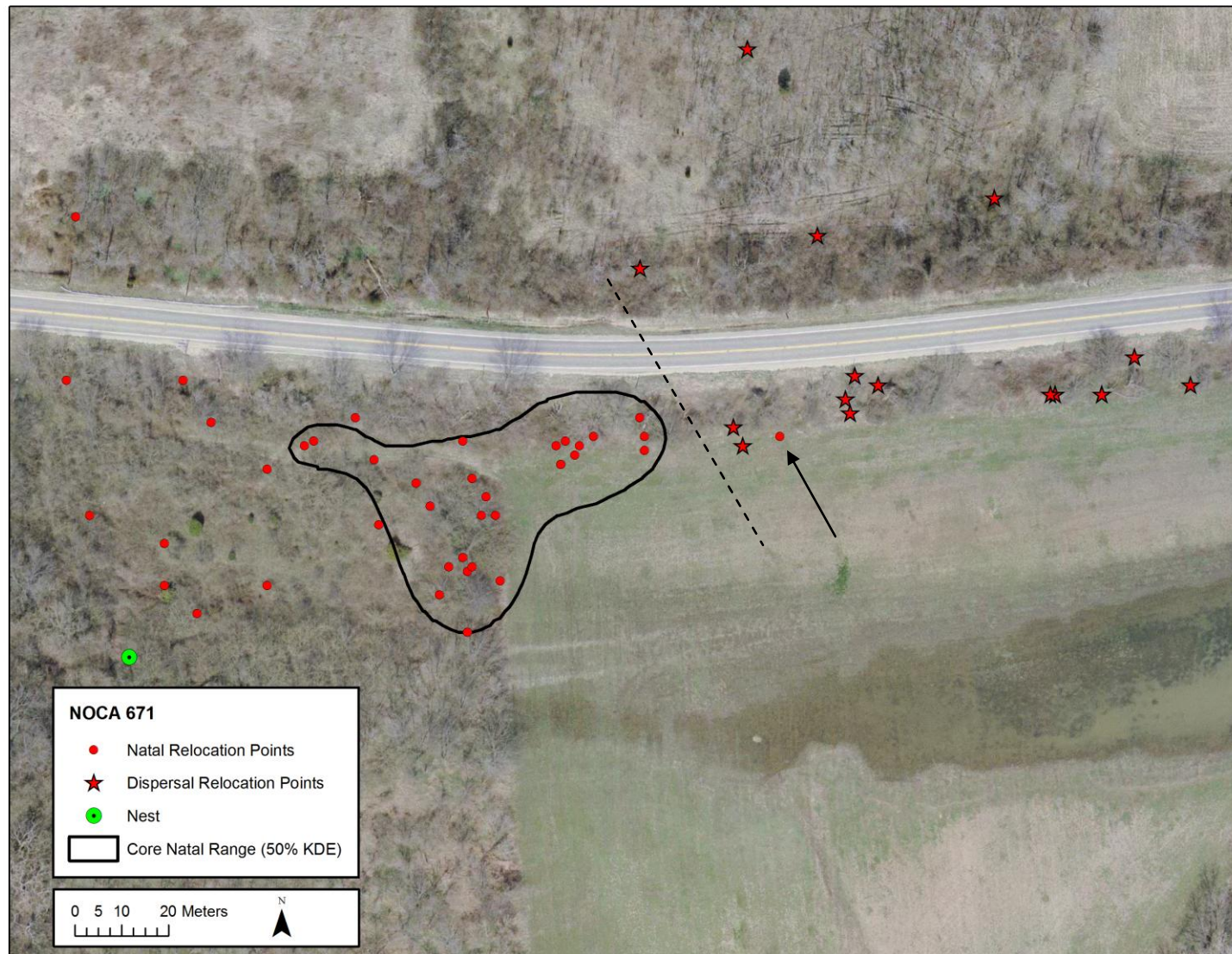


B



C

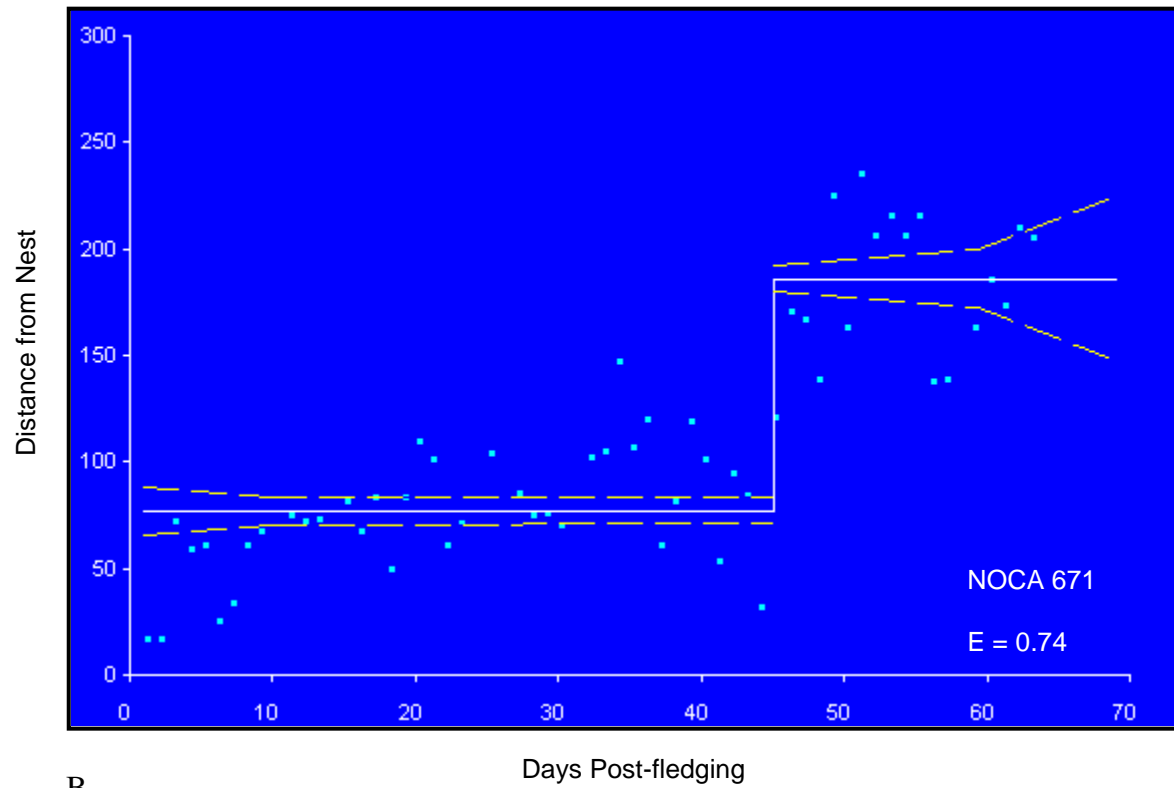
Figure 3.2. Example of local post-fledging dispersal by a fledgling Northern Cardinal (A) in central Ohio (2008) and the related segmented regression analysis (B). The coefficient of explanation (E) describes the amount of variation explained by the model and is similar to the correlation coefficient  $R^2$ . The regression breakpoint (vertical line) corresponds to the dashed line on the map. This individual made one exploratory movement 11 days prior to dispersing (arrow on the map).



A

continued

Figure 3.2 continued



B



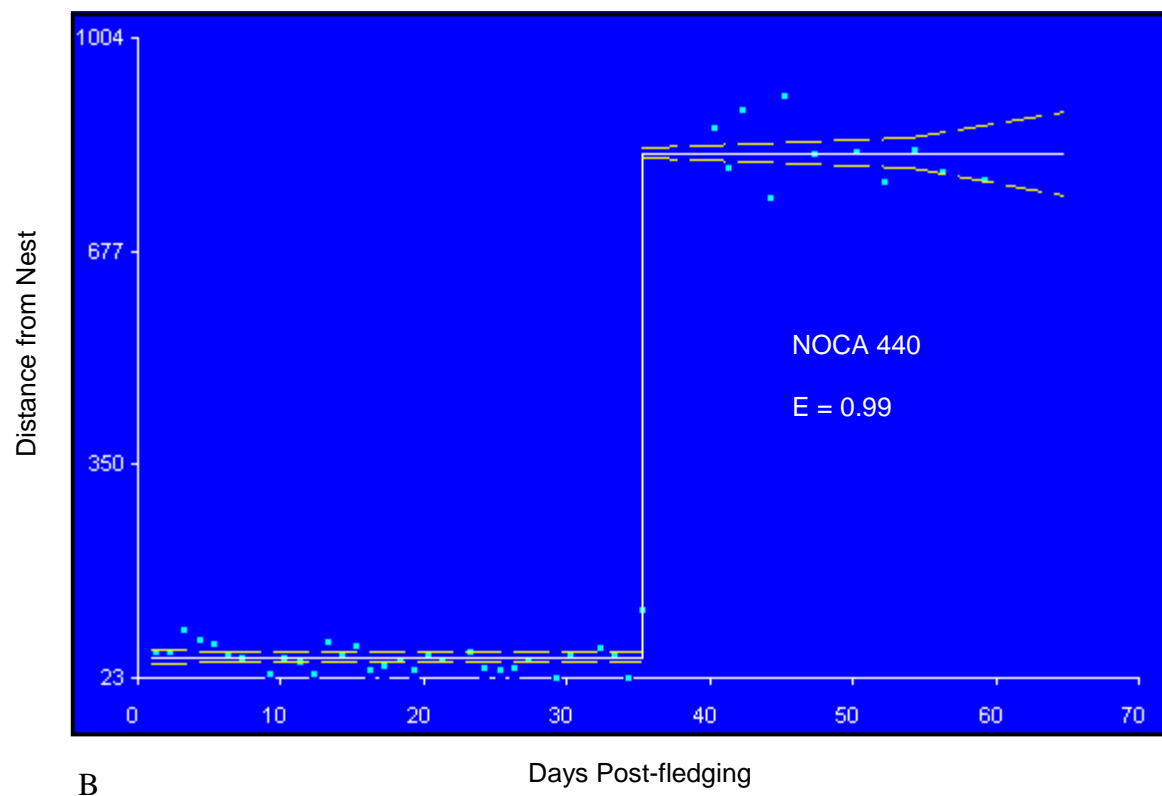
Figure 3.3. Example of extended post-fledging dispersal by a fledgling Northern Cardinal (A) in central Ohio (2008) and the related segmented regression analysis (B). The coefficient of explanation  $E$  describes the amount of variation explained by the model and is similar to the correlation coefficient  $R^2$ .



A

continued

Figure 3.3 continued



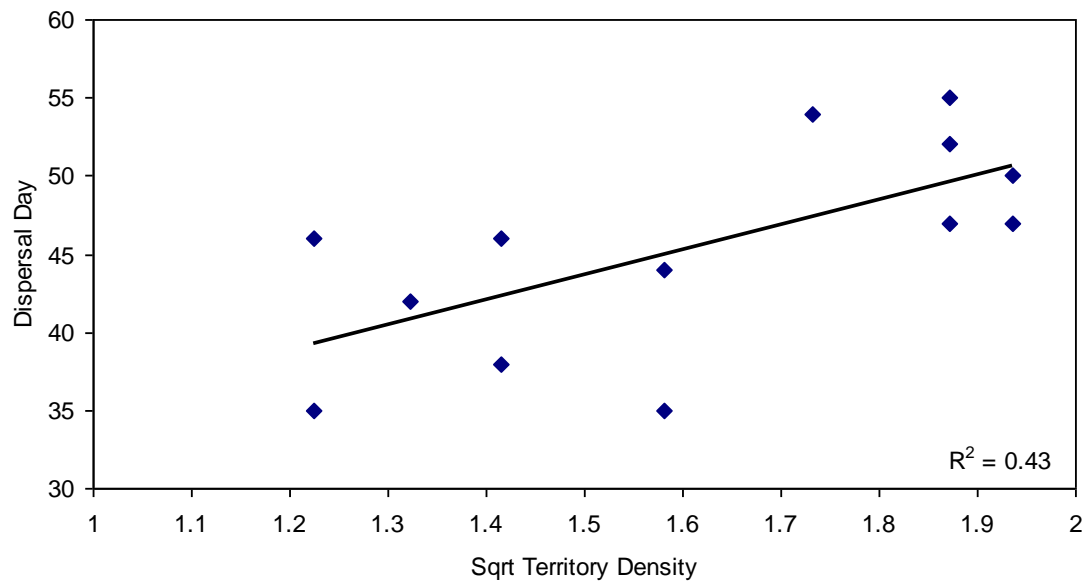


Figure 3.4. Association between the timing of post-fledging dispersal (days post-fledging) and conspecific territory density at the natal site for Northern Cardinals in central Ohio 2008 – 2009.  $n = 10$ .

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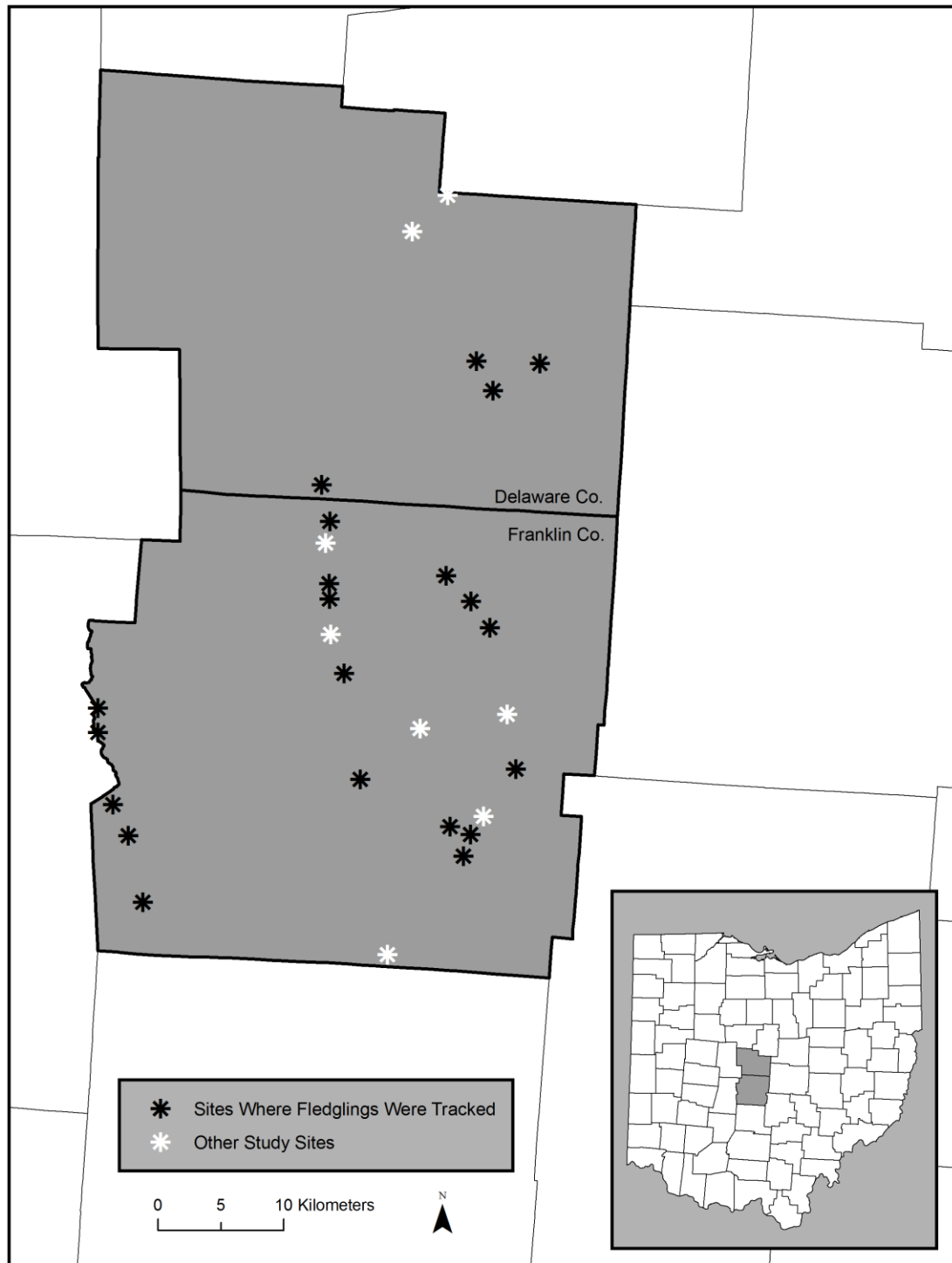


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#### Appendix A:

Location of riparian forest study sites where fledglings were tagged and where only nest searching occurred (Other Study Sites) in Delaware and Franklin Counties, Ohio, 2008-

2009



## Appendix B:

Coordinates for 21 riparian forests where fledglings were radio-tagged and tracked in  
central Ohio, 2008 – 2009

Site	Latitude	Longitude	County
Big Walnut	39.94430	-82.85602	Franklin
Camp Mary	40.12137	-83.03080	Franklin
Casto	40.08277	-82.92212	Franklin
Cherry	40.06433	-82.89855	Franklin
Creeks	39.88168	-82.90453	Franklin
Elk Run	39.89725	-82.89823	Franklin
Galena	40.21565	-82.87890	Delaware
Gardner	39.89492	-83.21672	Franklin
Girl Scout	39.96875	-83.24580	Franklin
Highbanks	40.14738	-83.03885	Delaware
Lou	39.93638	-83.00118	Franklin
Prairie Oaks	39.98628	-83.24587	Franklin
Public Hunting	39.84723	-83.20280	Franklin
Rush Run	40.07663	-83.03103	Franklin
South Galena	40.23683	-82.89458	Delaware
Smith	39.90273	-82.91700	Franklin
Sunbury	40.23527	-82.83522	Delaware
TNC	39.91700	-83.23150	Franklin
Woodside	40.04557	-82.88090	Franklin
Tuttle	40.01200	-83.01700	Franklin
Kenny	40.06600	-83.03100	Franklin

### Appendix C:

Distribution of radio-tagged fledglings in central Ohio, 2008 – 2009.

Day 1: First recorded day out of nest.

N: Number of relocation events.

Bird ID	Nest ID	Site	Date Tagged	Day 1	N	Days Tracked	Final Date	Fate
NOCA030CAST-09	09-04-104	Casto	5/8/2009	5/9/2009	46	71	7/18/2009	Survive
NOCA070LOUN-09	09-04-049	Lou N	5/12/2009	5/14/2009	5	6	18-May	Mortality - Unk.
NOCA151LOUS-09	09-04-047	Lou S	5/12/2009	5/13/2009	53	69	7/20/2009	Survive
NOCA191CREE-09	09-04-024	Creeks	5/14/2009	5/15/2009	46	57	7/10/2009	Survive
NOCA322ELKR-08	08-08-045	Elk Run	6/24/2008	6/25/2008	10	13	6/23/2008	Predation
NOCA340RRN -08	08-04-012	Rush Run N	5/30/2008	6/1/2008	55	59	7/29/2008	Survive
NOCA353TUTN-08	09-02-052	Tuttle N	5/15/2009	5/25/2009	7	7	5/25/2009	Predation
NOCA357RRS -08	08-03-036	Rush Run S	5/31/2008	6/1/2008	0	0	6/1/2008	Predation
NOCA379PUBH-08	08-07-021	Public Hunting	5/31/2008	6/1/2008	1	1	6/1/2008	Predation
NOCA379TUTN-08	08-07-058	Tuttle N	7/22/2008	7/24/2009	37	48	9/9/2008	Survive
NOCA379PRAI-08	08-07-034	Prairie Oaks	6/10/2008	6/13/2008	1	1	6/14/2008	Mortality - Exposure
NOCA390WOOD-08	08-04-093	Woodside	7/30/2008	7/31/2008	34	42	9/10/2009	Survive
NOCA410RRS -08	09-09-011	Rush Run S	5/15/2009	5/16/2008	1	1	5/16/2009	Predation - Coyote?
NOCA419TUTS-08	08-06-010	Tuttle S	7/22/2008	7/24/2008	1	1	7/25/2008	Predation - Hawk
NOCA440RRS -08	08-03-036	Rush Run S	5/31/2008	6/1/2008	42	59	7/29/2008	Survive
NOCA451PUBH-09	09-07-042	Public Hunting	5/16/2008	5/19/2008	0	0	5/19/2009	Predation
NOCA471PRAI-08	08-09-032	Prairie Oaks	6/3/2008	6/5/2008	46	55	7/29/2008	Survive
NOCA472PRAI-09	09-07-019	Prairie Oaks	5/22/2009	5/23/2009	48	57	7/18/2009	Survive
NOCA481PRAI-08	08-07-029	Prairie Oaks	6/7/2008	6/9/2008	1	1	6/10/2008	Predation
NOCA490PRAI-09	09-07-020	Prairie Oaks	5/23/2009	5/25/2009	45	48	7/11/2009	Survive

continued

Appendix C continued

Bird ID	Nest ID	Site	Date Tagged	Day 1	N	Days Tracked	Final Date	Fate
NOCA501ELKR-08	08-08-039	Elk Run	6/11/2008	6/12/2008	1	1	6/13/2008	Predation - Mammal
NOCA510LOUN-09	09-02-064	Lou N	5/25/2009	5/26/2009	42	56	7/20/2009	Survive
NOCA521PUBH-08	08-01-062	Public Hunting	6/18/2008	6/18/2009	1	1	6/19/2008	Predation - Red Squirrel
NOCA529PUBH-09	09-01-047	Public Hunting	5/25/2009	5/26/2009	0	0	5/26/2009	Predation - Red Fox
NOCA539TUTS-08	08-03-059	Tuttle S	6/27/2008	6/29/2008	1	1	6/30/2008	Predation - Mammal
NOCA539WOOD-08	08-05-063	Woodside	7/14/2008	7/14/2008	2	2	7/16/2008	Predation - Raptor
NOCA550RRN -09	09-07-041	Rush Run N	5/26/2009	5/28/2009	7	8	6/6/2009	Predation
NOCA559LOUN-08	08-08-055	Lou N	6/27/2008	6/29/2008	52	64	8/31/2008	Survive
NOCA571PUBH-09	09-01-049	Public Hunting	5/30/2009	5/31/2009	2	2	6/2/2009	Predation
NOCA580LOUS-08	08-08-057	Lou S	6/28/2008	6/29/2008	0	0	6/29/2008	Mortality - Drowned
NOCA580CAST-08	08-08-102	Casto	7/17/2008	7/18/2008	15	18	8/4/2008	Mortality - Disease
NOCA590SGAL-09	09-03-028	South Galena	6/1/2009	6/2/2009	45	54	7/25/2009	Survive
NOCA600TUTS-08	08-03-066	Tuttle S	7/5/2008	7/8/2008	46	56	9/2/2008	Survive
NOCA620LOUS-08	08-01-079	Lou S	7/25/2008	7/26/2008	37	46	9/9/2008	Survive
NOCA620TUTN-08	08-12-001	Tuttle N	7/2/2008	7/4/2008	0	0	7/4/2008	Predation - Mammal
NOCA630PUBH-09	09-07-049	Public Hunting	6/1/2009	6/2/2009	36	40	7/11/2008	Survive - Dropped Tag
NOCA640RRS -08	08-09-048	Rush Run S	7/4/2008	7/5/2008	1	1	7/6/2008	Predation - Raptor
NOCA649CHER-09	09-08-006	Cherry	6/4/2009	6/5/2009	49	62	8/5/2009	Survive
NOCA671PUBH-08	08-07-059	Public Hunting	7/10/2008	7/11/2008	57	63	9/11/2008	Survive
NOCA730SGAL-09	09-03-034	South Galena	6/5/2009	6/6/2009	45	55	7/30/2009	Survive
NOCA790ELKR-09	09-03-034	Elk Run	6/11/2009	6/14/2009	49	60	8/13/2009	Survive
NOCA829SGAL-09	09-06-050	South Galena	6/23/2009	6/24/2009	57	67	8/29/2009	Survive
NOCA850KENN-09	09-01-124	Kenny	7/8/2009	7/10/2009	46	62	9/9/2009	Survive

continued



Appendix C continued

Bird ID	Nest ID	Site	Date Tagged	Day 1	N	Days Tracked	Final Date	Fate
ACFL008CAMP-08	08-04-103	Camp Mary	8/14/2008	8/15/2008	3	4	8/14/2008	Survive - Tag Failed Early
ACFL029BIGW-08	08-04-104	Big Walnut	8/14/2008	8/15/2008	7	7	8/15/2008	Survive - Tag Failed Early
ACFL139TNC -08	08-07-049	TNC	7/21/2008	7/22/2008	9	10	7/31/2008	Survive - Tag Failed Early
ACFL158NGAL-08	08-04-071	North Galena	7/24/2008	7/25/2008	9	9	8/2/2008	Survive - Tag Failed Early
ACFL179PUBH-08	08-03-075	Public Hunting	7/28/2008	7/29/2008	5	7	8/4/2008	Survive - Tag Failed Early
ACFL199PUBH-08	08-03-075	Public Hunting	7/28/2008	7/29/2008	9	11	8/8/2008	Survive - Tag Failed Early
ACFL217GALE-08	08-04-098	Galena	8/1/2008	8/2/2008	14	15	8/16/2008	Survive - Tag Failed Early
ACFL218CAST-08	08-04-087	Casto	7/31/2008	8/1/2008	9	12	8/12/2008	Survive - Tag Failed Early
ACFL258GIRL-08	08-03-073	Girl Scout	8/6/2008	8/7/2008	9	10	8/16/2008	Survive - Tag Failed Early
ACFL298GARD-08	08-04-112	Gardner	8/11/2008	8/12/2008	10	14	8/25/2008	Survive - Tag Failed Early
ACFL398CAST-08	08-04-087	Casto	7/31/2008	8/1/2008	4	4	8/4/2008	Mortality
ACFL478TNC -08	08-02-051	TNC	8/7/2008	8/8/2008	21	21	8/28/2008	Survive
ACFL477TNC -09	09-01-070	TNC	6/29/2009	6/30/2009	22	22	7/21/2009	Survive
ACFL498TNC -09	09-01-070	TNC	6/29/2009	6/30/2009	21	21	7/20/2009	Survive
ACFL518BIGW-09	09-02-065	Big Walnut	6/29/2009	6/30/2009	22	22	7/21/2009	Survive
ACFL538CREE-09	09-02-067	Creeks	7/1/2009	7/2/2009	20	20	7/21/2009	Survive
ACFL559HIGH-09	09-02-100	High Banks	7/2/2009	7/2/2009	1	1	7/3/2009	Predation
ACFL578PUBH-09	09-07-122	Public Hunting	7/6/2009	7/7/2009	5	5	7/12/2009	Predation
ACFL599SMIT-09	09-02-079	Smith Farms	7/9/2009	7/10/2009	3	3	7/13/2009	Predation
ACFL618TNC -09	09-07-124	TNC	7/10/2009	7/11/2009	12	12	7/22/2009	Survive - Tag Failed Early

continued

Appendix C continued

Bird ID	Nest ID	Site	Date Tagged	Day 1	N	Days Tracked	Final Date	Fate
ACFL638SMIT-09	09-02-079	Smith Farms	7/15/2009	7/18/2009	14	14	8/1/2009	Predation - Raptor
ACFL658CREE-09	09-06-098	Creeks	7/20/2009	7/21/2009	20	20	8/9/2009	Survive
ACFL699SMIT-09	09-02-089	Smith Farms	7/27/2009	7/27/2009	19	19	8/15/2009	Survive
ACFL718TUTN-09	09-06-075	Tuttle N	7/27/2009	7/28/2009	17	18	8/14/2009	Survive
ACFL739CAST-09	09-09-037	Casto	8/1/2009	8/2/2009	22	22	8/23/2009	Survive
ACFL759WOOD-09	09-09-034	Woodside	8/1/2009	8/2/2009	22	22	8/23/2009	Survive
ACFL799ELKR-09	09-06-092	Elk Run	8/2/2009	8/3/2009	0	0	8/3/2009	Predation
ACFL818CREE-09	09-06-099	Creeks	8/3/2009	8/3/2009	1	1	8/4/2009	Predation
ACFL839SGAL-09	09-09-035	South Galena	8/7/2009	8/8/2009	18	18	8/25/2009	Survive
ACFL859SUNB-09	09-09-039	Sunbury	8/12/2009	8/13/2009	19	19	8/31/2009	Survive
ACFL998CREE-08	08-04-105	Creeks	8/20/2008	8/21/2008	10	11	9/1/2009	Survive - Tag Failed Early

#### Appendix D:

Covariates for survival analyses of fledglings in central Ohio, 2008-2009, using Program MARK known fate models.

Habitat variables are expressed as the mean with standard error.

N: Number of vegetation survey plots.

Bird	N	% Honeysuckle Cover	SE	% Native Shrub Cover	SE	Stems 3-8 cm DBH	SE	Stems 8-23 cm DBH	SE	Stems 23-38 cm DBH	SE	Stems >38 cm DBH	SE	Fledging Mass (g)	Fledging Day (Julian)	Urban Index
NOCA030CAST-09	10	0.56	0.06	3.53	0.43	3.70	0.19	2.71	0.17	1.42	0.10	1.36	0.12	24.5	129	1.25
NOCA071LOUN-09	4	0.99	0.04	2.49	0.15	5.71	0.68	4.12	0.04	2.48	0.53	1.22	0.00	23	134	1.26
NOCA151LOUS-09	23	0.65	0.05	3.96	0.23	4.39	0.26	3.65	0.31	1.73	0.13	1.08	0.09	24.5	133	1.26
NOCA191CREE-09	20	0.81	0.05	3.01	0.20	4.77	0.34	2.98	0.23	1.59	0.13	0.89	0.06	26	134	-0.71
NOCA322ELKR-08	5	0.47	0.04	5.35	0.39	3.79	0.36	4.60	0.16	1.83	0.43	0.91	0.13	23	177	-0.16
NOCA340RRN_-08	28	0.40	0.06	2.86	0.32	4.61	0.14	3.47	0.15	1.41	0.09	1.25	0.08	23	153	0.75
NOCA353TUTN-09	6	0.56	0.09	5.39	0.41	4.70	0.33	1.86	0.07	1.67	0.20	1.25	0.15	23	136	1.61
NOCA357RRS_-08	1	0.07	0.00	1.73	0.00	0.71	0.00	0.71	0.00	0.71	0.00	0.71	0.00	23.5	153	0.75
NOCA379PRAI-08	1	0.07	0.00	5.96	0.00	1.58	0.00	0.71	0.00	0.71	0.00	0.71	0.00	24	165	-1.12
NOCA379PUBH-08	1	0.42	0.00	0.87	0.00	2.74	0.00	1.58	0.00	1.87	0.00	0.71	0.00	28	153	-1.15
NOCA379TUTN-08	16	0.18	0.06	7.19	0.39	3.81	0.32	2.81	0.30	1.54	0.11	1.17	0.11	27.5	206	1.61
NOCA390WOOD-08	13	0.64	0.05	4.75	0.27	2.75	0.23	3.57	0.34	1.39	0.19	0.87	0.07	22	213	0.32
NOCA410RRS_-09	1	0.07	0.00	3.67	0.00	4.85	0.00	3.94	0.00	2.35	0.00	1.22	0.00	27	136	0.75
NOCA419CAST-08	4	0.17	0.03	5.41	0.34	3.64	0.71	3.36	0.40	1.47	0.44	1.77	0.19	23	156	1.25
NOCA440RRS_-08	12	0.81	0.08	3.27	0.56	4.93	0.56	3.37	0.23	1.36	0.17	1.01	0.11	19	153	0.75
NOCA451PUBH-09	1	0.55	0.00	4.95	0.00	4.95	0.00	2.35	0.00	1.58	0.00	2.12	0.00	26	139	-1.15
NOCA471PRAI-08	26	0.31	0.04	4.23	0.40	3.69	0.22	4.29	0.19	1.52	0.11	1.03	0.08	27	157	-1.12
NOCA472PRAI-09	26	0.31	0.05	3.38	0.18	5.73	0.43	3.78	0.25	1.72	0.13	1.05	0.07	25	143	-1.12
NOCA481PRAI-08	1	0.31	0.00	7.45	0.00	3.81	0.00	5.34	0.00	2.12	0.00	1.87	0.00	24	161	-1.12
NOCA490PRAI-09	27	0.42	0.04	3.06	0.14	6.09	0.34	5.05	0.21	1.83	0.17	1.38	0.11	25	145	-1.12

continued

Appendix D continued

Bird	N	% Honeysuckle Cover	SE	% Native Shrub Cover	SE	Stems 3-8 cm DBH	SE	Stems 8-23 cm DBH	SE	Stems 23-38 cm DBH	SE	Stems >38 cm DBH	SE	Fledging Mass (g)	Fledging Day (Julian)	Urban Index
NOCA501ELKR-08	1	0.72	0.00	1.18	0.00	0.71	0.00	2.74	0.00	1.87	0.00	1.22	0.00	27	164	-0.16
NOCA510LOUN-09	21	0.78	0.06	3.81	0.25	3.66	0.23	3.52	0.17	2.27	0.21	1.60	0.13	23	146	1.26
NOCA521PUBH-08	1	0.77	0.00	1.00	0.00	3.81	0.00	2.35	0.00	0.71	0.00	0.71	0.00	22.5	171	-1.15
NOCA529PUBH-09	1	0.36	0.00	4.09	0.00	3.24	0.00	1.87	0.00	1.58	0.00	0.71	0.00	26	146	-1.15
NOCA539TUTS-08	1	0.92	0.00	3.46	0.00	6.44	0.00	2.55	0.00	1.58	0.00	1.58	0.00	23	181	1.61
NOCA539WOOD-08	2	0.44	0.14	3.41	1.12	1.85	0.27	3.65	0.41	1.58	0.00	1.22	0.00	25.5	196	0.32
NOCA550RRN_-09	5	0.56	0.05	2.02	0.32	4.59	0.40	3.77	0.13	2.14	0.16	0.71	0.00	27.5	148	0.75
NOCA559LOUN-08	23	0.78	0.06	2.95	0.19	3.57	0.32	3.32	0.15	1.55	0.16	1.07	0.08	28.5	181	1.26
NOCA571PUBH-09	1	0.45	0.00	1.22	0.00	6.04	0.00	2.12	0.00	1.58	0.00	1.22	0.00	26.5	151	-1.15
NOCA580CAST-08	5	1.03	0.03	1.48	0.08	5.36	0.21	2.90	0.15	2.60	0.20	1.65	0.20	24	200	1.25
NOCA580LOUS-08	1	1.18	0.00	1.32	0.00	2.35	0.00	4.30	0.00	3.08	0.00	0.71	0.00	26.5	181	1.26
NOCA590SGAL-09	23	0.18	0.02	4.58	0.18	3.39	0.23	3.47	0.09	1.44	0.14	1.05	0.07	28.5	153	-0.57
NOCA600TUTS-08	22	0.75	0.04	4.14	0.31	4.77	0.30	3.65	0.21	1.56	0.11	1.17	0.08	23.5	190	1.61
NOCA620LOUS-08	16	0.58	0.04	3.63	0.27	3.88	0.23	3.76	0.26	1.41	0.15	0.85	0.10	28.5	208	1.26
NOCA630PUBH-09	25	0.44	0.05	3.16	0.18	4.71	0.26	3.15	0.11	2.04	0.10	1.67	0.10	25	153	-1.15
NOCA640RRS_-08	1	0.13	0.00	1.00	0.00	3.81	0.00	3.81	0.00	2.12	0.00	2.55	0.00	24	187	0.75
NOCA649CHER-09	24	0.11	0.01	5.71	0.35	3.70	0.30	2.06	0.11	1.37	0.12	1.14	0.08	23.5	156	0.76
NOCA671PUBH-08	23	0.57	0.05	4.86	0.38	5.17	0.25	3.60	0.21	1.23	0.10	0.73	0.02	24	193	-1.15
NOCA730SGAL-09	29	0.16	0.02	3.97	0.26	3.40	0.21	3.21	0.27	1.80	0.12	1.01	0.05	25	157	-0.57
NOCA790ELKR-09	24	0.60	0.05	3.83	0.18	3.87	0.16	3.24	0.11	1.85	0.13	1.12	0.08	25.5	161	-0.16
NOCA829SGAL-09	21	0.43	0.06	3.79	0.53	4.63	0.16	3.09	0.15	1.21	0.13	0.97	0.11	25	175	-0.57
NOCA850KENN-09	20	0.58	0.02	4.26	0.14	3.74	0.30	2.42	0.15	1.23	0.12	1.53	0.09	28	191	0.89
NOCA930CREE-09	1	0.07	0.00	7.11	0.00	4.53	0.00	3.39	0.00	1.87	0.00	1.87	0.00	25	192	-0.71

continued

Appendix D continued

Bird	N	% Honeysuckle Cover	SE	% Native Shrub Cover	SE	Stems 3-8 cm DBH	SE	Stems 8-23 cm DBH	SE	Stems 23-38 cm DBH	SE	Stems >38 cm DBH	SE	Fledging Mass (g)	Fledging Day (Julian)	Urban Index
ACFL008CAMP-08	4	0.08	0.01	4.31	0.07	3.30	0.60	3.22	0.19	1.87	0.00	0.84	0.13	10.5	228	0.21
ACFL029BIGW-08	7	0.44	0.12	6.33	0.58	4.49	0.19	3.27	0.21	1.91	0.15	0.95	0.17	11.5	228	1.31
ACFL139TNC_-08	10	0.32	0.07	6.25	0.53	4.16	0.26	4.20	0.25	1.44	0.19	1.01	0.14	11.5	204	-0.96
ACFL158NGAL-08	9	0.07	0.00	3.45	0.34	3.06	0.22	3.40	0.13	1.59	0.11	1.03	0.11	12	207	-1.27
ACFL179PUBH-08	6	0.36	0.11	3.37	0.98	3.04	1.22	3.00	0.58	1.38	0.15	1.57	0.20	11.5	211	-1.15
ACFL199PUBH-08	8	0.51	0.12	3.76	0.66	4.00	0.89	3.21	0.49	1.23	0.13	1.21	0.20	9	211	-1.15
ACFL217GALE-08	14	0.12	0.03	4.50	0.32	3.49	0.26	3.96	0.23	2.01	0.18	1.25	0.15	10.5	215	-0.48
ACFL218CAST-08	10	0.16	0.04	3.90	0.55	2.34	0.34	3.57	0.20	1.41	0.18	1.10	0.14	10.5	214	1.25
ACFL258GIRL-08	9	0.45	0.14	1.69	0.46	4.37	0.76	3.33	0.38	1.14	0.28	0.71	0.00	11	220	-0.82
ACFL298GARD-08	10	0.29	0.08	5.67	0.56	3.31	0.28	3.20	0.19	1.78	0.13	1.04	0.12	10.5	225	-0.87
ACFL398CAST-08	4	0.17	0.05	4.22	0.89	2.82	0.32	3.90	0.13	1.30	0.43	0.93	0.22	10	214	1.25
ACFL477TNC_-09	20	0.41	0.05	4.60	0.22	6.71	0.21	4.66	0.15	2.29	0.10	0.94	0.06	10	181	-0.96
ACFL478TNC_-08	19	0.23	0.03	4.36	0.31	3.59	0.27	4.34	0.21	1.80	0.18	1.04	0.08	11	221	-0.96
ACFL498TNC_-09	16	0.40	0.07	4.29	0.28	6.67	0.16	4.73	0.19	2.40	0.09	1.00	0.07	12	181	-0.96
ACFL518BIGW-09	19	0.24	0.06	5.40	0.40	4.07	0.38	3.06	0.13	1.77	0.07	1.28	0.15	11.5	181	1.31
ACFL538CREE-09	19	0.07	0.00	4.29	0.21	1.68	0.16	2.62	0.11	1.49	0.13	1.50	0.14	11	183	-0.71
ACFL558HIGH-09	1	0.07	0.00	4.39	0.00	3.08	0.00	2.12	0.00	1.58	0.00	1.58	0.00	11	184	-0.3
ACFL578PUBH-09	5	0.20	0.01	6.11	0.62	4.56	0.37	3.18	0.04	1.91	0.10	2.00	0.15	11	188	-1.15
ACFL599SMIT-09	3	0.09	0.02	3.74	0.35	1.22	0.00	1.60	0.37	2.32	0.23	2.86	0.06	11	191	-0.28
ACFL618TNC_-09	11	0.20	0.01	3.05	0.34	5.89	0.42	4.35	0.14	2.43	0.15	1.46	0.14	13	192	-0.96

continued

Appendix D continued

Bird	N	% Honeysuckle Cover	SE	% Native Shrub Cover	SE	Stems 3-8 cm DBH	SE	Stems 8-23 cm DBH	SE	Stems 23-38 cm DBH	SE	Stems >38 cm DBH	SE	Fledging Mass (g)	Fledging Day (Julian)	Urban Index
ACFL638SMIT-09	12	0.29	0.06	3.89	0.37	2.32	0.38	2.78	0.12	1.80	0.16	1.91	0.15	12.5	199	-0.28
ACFL658CREE-09	19	0.21	0.05	4.23	0.32	3.25	0.38	2.68	0.10	1.55	0.09	1.12	0.11	11	202	-0.71
ACFL699SMIT-09	18	0.64	0.04	3.30	0.21	3.84	0.27	2.26	0.20	1.76	0.13	1.78	0.10	11.5	208	-0.28
ACFL718TUTN-09	16	0.47	0.08	5.31	0.35	5.56	0.42	3.01	0.32	1.37	0.11	1.34	0.13	11	209	1.61
ACFL739CAST-09	20	0.32	0.06	4.74	0.26	3.53	0.39	2.63	0.16	1.58	0.15	1.52	0.12	11	214	1.25
ACFL759WOOD-09	20	0.12	0.02	4.58	0.28	3.79	0.36	3.08	0.16	1.69	0.09	1.38	0.10	11	214	0.32
ACFL799ELKR-09	1	0.50	0.00	4.80	0.00	5.05	0.00	3.24	0.00	1.22	0.00	1.58	0.00	11.5	215	-0.16
ACFL818CREE-09	1	0.12	0.00	5.74	0.00	3.54	0.00	2.35	0.00	1.87	0.00	1.58	0.00	11.5	215	-0.71
ACFL839SGAL-09	16	0.09	0.01	4.92	0.21	4.10	0.20	3.47	0.18	2.26	0.07	1.14	0.10	11	220	-0.57
ACFL859SUNB-09	17	0.07	0.00	6.16	0.17	4.99	0.15	2.62	0.20	1.87	0.15	1.18	0.12	10	225	-0.42
ACFL998CREE-08	10	0.07	0.00	4.69	0.47	1.60	0.20	2.69	0.17	1.64	0.10	1.88	0.17	11	234	-0.71

#### Appendix E:

Microhabitat structures at fledgling relocation points and random plots in central Ohio, 2008-2009.

Habitat variables are expressed as the mean with standard error.

N: Number of vegetation survey plots.



Bird	Plot Type	N	% Honeysuckle Cover	SE	% Native Shrub Cover	SE	% Other Cover	SE	Stems 3-8 cm DBH	SE	Stems 8-23 cm DBH	SE	Stems 23-38 cm DBH	SE	Stems >38 cm DBH	SE
NOCA030CAST-09	Relocation	10	0.56	0.06	3.53	0.43	0.85	0.14	3.70	0.19	2.71	0.17	1.42	0.10	1.36	0.12
	Random	10	0.44	0.09	2.96	0.32	0.77	0.06	3.48	0.28	2.94	0.16	1.24	0.13	1.16	0.08
NOCA071LOUN-09	Relocation	4	0.99	0.04	2.49	0.15	0.71	0.00	5.71	0.68	4.12	0.04	2.48	0.53	1.22	0.00
	Random	4	0.68	0.06	2.87	0.14	0.71	0.00	3.42	0.11	3.69	0.55	2.76	0.36	1.60	0.38
NOCA151LOUS-09	Relocation	23	0.65	0.05	3.96	0.23	0.71	0.00	4.39	0.26	3.65	0.31	1.73	0.13	1.08	0.09
	Random	24	0.51	0.06	3.76	0.24	0.71	0.00	3.22	0.33	3.67	0.27	1.77	0.14	1.46	0.11
NOCA191CREE-09	Relocation	20	0.81	0.05	3.01	0.20	0.71	0.00	4.77	0.34	2.98	0.23	1.59	0.13	0.89	0.06
	Random	20	0.50	0.07	3.48	0.30	0.89	0.18	4.13	0.34	3.24	0.25	1.69	0.15	1.10	0.10
NOCA322ELKR-08	Relocation	5	0.47	0.04	5.35	0.39	1.98	0.67	3.79	0.36	4.60	0.16	1.83	0.43	0.91	0.13
	Random	5	0.55	0.07	4.22	0.23	1.26	0.55	3.56	0.64	3.67	0.41	1.55	0.42	1.23	0.21
NOCA340RRN_-08	Relocation	28	0.40	0.06	2.86	0.32	1.13	0.10	4.61	0.14	3.47	0.15	1.41	0.09	1.25	0.08
	Random	22	0.33	0.03	2.80	0.31	1.41	0.17	4.38	0.16	3.57	0.15	1.32	0.10	1.41	0.10
NOCA353TUTN-09	Relocation	6	0.56	0.09	5.39	0.41	0.71	0.00	4.70	0.33	1.86	0.07	1.67	0.20	1.25	0.15
	Random	6	0.37	0.11	5.02	0.47	0.71	0.00	4.48	0.51	2.63	0.23	1.76	0.21	1.47	0.18
NOCA379TUTN-08	Relocation	16	0.18	0.06	7.19	0.39	1.54	0.28	3.81	0.32	2.81	0.30	1.54	0.11	1.17	0.11
	Random	17	0.15	0.04	6.98	0.36	0.83	0.06	3.39	0.31	3.23	0.28	1.79	0.09	1.17	0.09
NOCA390WOOD-08	Relocation	13	0.64	0.05	4.75	0.27	2.79	0.45	2.75	0.23	3.57	0.34	1.39	0.19	0.87	0.07
	Random	13	0.55	0.03	4.75	0.49	2.95	0.39	2.01	0.18	3.96	0.15	1.96	0.05	0.93	0.09

continued

Appendix E continued

Bird	Plot Type	N	% Honeysuckle Cover	SE	% Native Shrub Cover	SE	% Other Cover	SE	Stems 3-8 cm DBH	SE	Stems 8-23 cm DBH	SE	Stems 23-38 cm DBH	SE	Stems >38 cm DBH	SE
NOCA419CAST-08	Relocation	4	0.17	0.03	5.41	0.34	0.71	0.00	3.64	0.71	3.36	0.40	1.47	0.44	1.77	0.19
	Random	4	0.31	0.09	6.78	0.19	0.71	0.00	4.21	0.50	3.24	0.57	1.68	0.24	1.22	0.00
NOCA440RRS_-08	Relocation	12	0.81	0.08	3.27	0.56	1.28	0.53	4.93	0.56	3.37	0.23	1.36	0.17	1.01	0.11
	Random	15	0.54	0.08	3.66	0.55	0.71	0.00	4.54	0.35	3.85	0.22	1.73	0.25	1.45	0.14
NOCA471PRAI-08	Relocation	26	0.31	0.04	4.23	0.40	1.13	0.12	3.69	0.22	4.29	0.19	1.52	0.11	1.03	0.08
	Random	24	0.17	0.03	3.36	0.36	0.85	0.10	2.65	0.36	2.72	0.34	1.39	0.13	1.07	0.09
NOCA472PRAI-09	Relocation	26	0.31	0.05	3.38	0.18	1.91	0.17	5.73	0.43	3.78	0.25	1.72	0.13	1.05	0.07
	Random	26	0.24	0.03	2.24	0.13	1.79	0.15	4.58	0.32	3.36	0.25	2.09	0.16	1.43	0.12
NOCA490PRAI-09	Relocation	27	0.42	0.04	3.06	0.14	1.73	0.14	6.09	0.34	5.05	0.21	1.83	0.17	1.38	0.11
	Random	27	0.35	0.04	2.78	0.18	1.92	0.23	6.03	0.33	4.65	0.18	2.28	0.15	1.40	0.12
NOCA510LOUN-09	Relocation	21	0.78	0.06	3.81	0.25	0.73	0.02	3.66	0.23	3.52	0.17	2.27	0.21	1.60	0.13
	Random	21	0.51	0.07	3.89	0.24	0.71	0.00	3.15	0.38	3.08	0.17	2.05	0.13	1.67	0.13
NOCA539TUTS-08	Relocation	1	0.92	0.00	3.46	0.00	0.71	0.00	6.44	0.00	2.55	0.00	1.58	0.00	1.58	0.00
	Random	1	0.64	0.00	6.36	0.00	0.71	0.00	6.44	0.00	3.39	0.00	0.71	0.00	1.58	0.00
NOCA550RRN_-09	Relocation	5	0.56	0.05	2.02	0.32	0.71	0.00	4.59	0.40	3.77	0.13	2.14	0.16	0.71	0.00
	Random	5	0.51	0.08	3.30	0.50	0.93	0.22	4.83	0.59	3.48	0.23	1.87	0.39	1.02	0.13
NOCA559LOUN-08	Relocation	23	0.78	0.06	2.95	0.19	0.80	0.07	3.57	0.32	3.32	0.15	1.55	0.16	1.07	0.08
	Random	23	0.40	0.05	3.84	0.27	0.81	0.07	2.76	0.23	2.99	0.17	1.69	0.17	1.17	0.10

continued

Appendix E continued

Bird	Plot Type	N	% Honeysuckle Cover	SE	% Native Shrub Cover	SE	% Other Cover	SE	Stems 3-8 cm DBH	SE	Stems 8-23 cm DBH	SE	Stems 23-38 cm DBH	SE	Stems >38 cm DBH	SE
NOCA580CAST-08	Relocation	5	1.03	0.03	1.48	0.08	0.71	0.00	5.36	0.21	2.90	0.15	2.60	0.20	1.65	0.20
	Random	5	0.75	0.14	2.06	0.37	0.79	0.08	3.73	0.54	3.46	0.29	1.72	0.19	0.99	0.18
NOCA590SGAL-09	Relocation	23	0.18	0.02	4.58	0.18	0.80	0.06	3.39	0.23	3.47	0.09	1.44	0.14	1.05	0.07
	Random	20	0.14	0.02	3.71	0.19	0.75	0.05	3.04	0.23	3.23	0.22	1.50	0.11	1.32	0.13
NOCA600TUTS-08	Relocation	22	0.75	0.04	4.14	0.31	0.73	0.02	4.77	0.30	3.65	0.21	1.56	0.11	1.17	0.08
	Random	22	0.52	0.07	5.49	0.45	0.80	0.06	4.29	0.21	3.22	0.26	1.57	0.12	1.48	0.09
NOCA620LOUS-08	Relocation	16	0.58	0.04	3.63	0.27	0.71	0.00	3.88	0.23	3.76	0.26	1.41	0.15	0.85	0.10
	Random	16	0.30	0.04	3.49	0.24	0.78	0.06	1.96	0.19	3.94	0.24	1.53	0.14	1.14	0.13
NOCA630PUBH-09	Relocation	25	0.44	0.05	3.16	0.18	3.54	0.40	4.71	0.26	3.15	0.11	2.04	0.10	1.67	0.10
	Random	25	0.32	0.03	3.13	0.14	3.12	0.26	4.15	0.24	3.33	0.17	2.04	0.10	1.71	0.11
NOCA649CHER-09	Relocation	24	0.11	0.01	5.71	0.35	1.81	0.18	3.70	0.30	2.06	0.11	1.37	0.12	1.14	0.08
	Random	21	0.09	0.01	3.99	0.34	1.15	0.15	3.38	0.26	2.46	0.14	1.42	0.11	1.27	0.12
NOCA671PUBH-08	Relocation	23	0.57	0.05	4.86	0.38	2.00	0.32	5.17	0.25	3.60	0.21	1.23	0.10	0.73	0.02
	Random	23	0.52	0.05	3.88	0.30	2.12	0.29	4.45	0.31	3.87	0.31	1.10	0.10	0.71	0.00
NOCA790ELKR-09	Relocation	24	0.60	0.05	3.83	0.18	2.83	0.30	3.87	0.16	3.24	0.11	1.85	0.13	1.12	0.08
	Random	25	0.47	0.04	4.06	0.26	1.11	0.15	3.88	0.21	3.15	0.12	1.81	0.13	1.28	0.09

continued

Appendix E continued

Bird	Plot Type	N	% Honeysuckle Cover		% Native Shrub Cover		% Other Cover		Stems 3-8 cm DBH		Stems 8-23 cm DBH		Stems 23-38 cm DBH		Stems >38 cm DBH	
				SE		SE		SE		SE		SE		SE		SE
NOCA829SGAL-09	Relocation	21	0.43	0.06	3.79	0.53	1.24	0.20	4.63	0.16	3.09	0.15	1.21	0.13	0.97	0.11
	Random	19	0.13	0.02	3.04	0.40	1.04	0.18	3.25	0.28	3.50	0.40	1.50	0.19	1.31	0.17
NOCA850KENN-09	Relocation	20	0.58	0.02	4.26	0.14	0.71	0.00	3.74	0.30	2.42	0.15	1.23	0.12	1.53	0.09
	Random	20	0.26	0.06	3.94	0.23	0.71	0.00	3.79	0.41	2.68	0.14	1.50	0.13	1.18	0.09

continued

## Appendix E continued

Bird	Plot Type	N	% Honeysuckle Cover	SE	% Native Shrub Cover	SE	% Other Cover	SE	Stems 3-8 cm DBH	SE	Stems 8-23 cm DBH	SE	Stems 23-38 cm DBH	SE	Stems >38 cm DBH	SE
ACFL008CAMP-08	Relocation	4	0.08	0.01	4.31	0.07	0.71	0.00	3.30	0.60	3.22	0.19	1.87	0.00	0.84	0.13
	Random	4	0.10	0.03	3.40	0.94	0.81	0.10	2.58	0.15	3.34	0.20	2.17	0.11	1.10	0.13
ACFL029BIGW-08	Relocation	7	0.44	0.12	6.33	0.58	2.02	0.66	4.49	0.19	3.27	0.21	1.91	0.15	0.95	0.17
	Random	7	0.40	0.09	6.40	0.59	1.77	0.47	3.69	0.38	3.80	0.29	1.92	0.20	1.38	0.17
ACFL139TNC_-08	Relocation	10	0.32	0.07	6.25	0.53	1.13	0.12	4.16	0.26	4.20	0.25	1.44	0.19	1.01	0.14
	Random	10	0.31	0.06	6.16	0.58	1.23	0.19	4.11	0.25	4.43	0.25	1.68	0.15	0.91	0.08
ACFL158NGAL-08	Relocation	9	0.07	0.00	3.45	0.34	0.71	0.00	3.06	0.22	3.40	0.13	1.59	0.11	1.03	0.11
	Random	9	0.07	0.00	2.98	0.43	0.71	0.00	2.58	0.22	2.71	0.18	1.69	0.20	1.54	0.13
ACFL179PUBH-08	Relocation	6	0.36	0.11	3.37	0.98	1.19	0.48	3.04	1.22	3.00	0.58	1.38	0.15	1.57	0.20
	Random	6	0.46	0.17	4.12	0.86	0.91	0.20	3.70	1.25	3.14	0.44	1.41	0.27	1.46	0.37
ACFL199PUBH-08	Relocation	8	0.51	0.12	3.76	0.66	0.71	0.00	4.00	0.89	3.21	0.49	1.23	0.13	1.21	0.20
	Random	8	0.36	0.07	3.22	0.25	0.86	0.15	2.41	0.37	4.04	0.25	1.79	0.20	1.50	0.23
ACFL217GALE-08	Relocation	14	0.12	0.03	4.50	0.32	0.71	0.00	3.49	0.26	3.96	0.23	2.01	0.18	1.25	0.15
	Random	14	0.10	0.02	3.30	0.36	0.78	0.07	3.00	0.25	3.64	0.25	2.24	0.11	1.43	0.15
ACFL218CAST-08	Relocation	10	0.16	0.04	3.90	0.55	0.81	0.07	2.34	0.34	3.57	0.20	1.41	0.18	1.10	0.14
	Random	10	0.12	0.04	3.29	0.37	0.87	0.16	1.87	0.33	3.11	0.37	1.29	0.19	1.41	0.15
ACFL258GIRL-08	Relocation	9	0.45	0.14	1.69	0.46	4.64	0.91	4.37	0.76	3.33	0.38	1.14	0.28	0.71	0.00
	Random	9	0.32	0.11	2.03	0.48	2.60	0.77	2.30	0.41	3.86	0.22	1.66	0.37	1.34	0.21

continued

Appendix E continued

Bird	Plot Type	N	% Honeysu ckle Cover	SE	% Native Shrub Cover	SE	% Other Cover	SE	Stems 3-8 cm DBH	SE	Stems 8-23 cm DBH	SE	Stems 23-38 cm DBH	SE	Stems >38 cm DBH	SE
ACFL298GARD-08	Relocation	10	0.29	0.08	5.67	0.56	1.42	0.26	3.31	0.28	3.20	0.19	1.78	0.13	1.04	0.12
	Random	10	0.22	0.02	4.48	0.49	1.61	0.24	2.54	0.31	3.07	0.15	1.76	0.19	1.14	0.10
ACFL398CAST-08	Relocation	4	0.17	0.05	4.22	0.89	0.71	0.00	2.82	0.32	3.90	0.13	1.30	0.43	0.93	0.22
	Random	4	0.07	0.00	2.89	0.29	0.71	0.00	1.58	0.50	2.36	0.38	1.39	0.44	1.27	0.21
ACFL477TNC_-09	Relocation	20	0.41	0.05	4.60	0.22	2.55	0.20	6.71	0.21	4.66	0.15	2.29	0.10	0.94	0.06
	Random	20	0.36	0.05	3.53	0.19	2.77	0.21	5.96	0.24	4.64	0.12	2.32	0.12	1.09	0.09
ACFL478TNC_-08	Relocation	19	0.23	0.03	4.36	0.31	2.27	0.47	3.59	0.27	4.34	0.21	1.80	0.18	1.04	0.08
	Random	19	0.25	0.04	4.43	0.31	1.92	0.35	2.97	0.23	4.25	0.19	1.85	0.15	1.01	0.10
ACFL498TNC_-09	Relocation	16	0.40	0.07	4.29	0.28	2.21	0.22	6.67	0.16	4.73	0.19	2.40	0.09	1.00	0.07
	Random	17	0.42	0.07	3.14	0.20	2.69	0.26	6.02	0.31	4.78	0.13	2.39	0.13	1.14	0.11
ACFL518BIGW-09	Relocation	19	0.24	0.06	5.40	0.40	0.71	0.00	4.07	0.38	3.06	0.13	1.77	0.07	1.28	0.15
	Random	19	0.20	0.04	5.27	0.25	0.82	0.11	3.59	0.23	2.93	0.19	1.75	0.11	1.45	0.12
ACFL538CREE-09	Relocation	19	0.07	0.00	4.29	0.21	0.71	0.00	1.68	0.16	2.62	0.11	1.49	0.13	1.50	0.14
	Random	19	0.08	0.01	4.35	0.27	0.71	0.00	1.90	0.21	2.75	0.12	1.58	0.12	1.62	0.12
ACFL578PUBH-09	Relocation	5	0.20	0.01	6.11	0.62	1.82	0.57	4.56	0.37	3.18	0.04	1.91	0.10	2.00	0.15
	Random	5	0.25	0.06	3.35	0.29	2.32	0.36	2.93	0.36	2.48	0.37	2.62	0.25	1.84	0.18
ACFL599SMIT-09	Relocation	3	0.09	0.02	3.74	0.35	0.71	0.00	1.22	0.00	1.60	0.37	2.32	0.23	2.86	0.06
	Random	3	0.51	0.02	3.54	0.21	0.71	0.00	1.46	0.12	2.54	0.11	1.44	0.22	1.93	0.22

continued

## Appendix E continued

Bird	Plot Type	N	% Honeysuckle Cover	SE	% Native Shrub Cover	SE	% Other Cover	SE	Stems 3-8 cm DBH	SE	Stems 8-23 cm DBH	SE	Stems 23-38 cm DBH	SE	Stems >38 cm DBH	SE
ACFL618TNC_-09	Relocation	11	0.20	0.01	3.05	0.34	1.59	0.13	5.89	0.42	4.35	0.14	2.43	0.15	1.46	0.14
	Random	11	0.25	0.03	1.93	0.17	2.28	0.22	5.34	0.29	4.83	0.17	2.39	0.16	1.31	0.12
ACFL618TNC_-09	Relocation	11	0.20	0.01	3.05	0.34	1.59	0.13	5.89	0.42	4.35	0.14	2.43	0.15	1.46	0.14
	Random	11	0.25	0.03	1.93	0.17	2.28	0.22	5.34	0.29	4.83	0.17	2.39	0.16	1.31	0.12
ACFL638SMIT-09	Relocation	12	0.29	0.06	3.89	0.37	0.71	0.00	2.32	0.38	2.78	0.12	1.80	0.16	1.91	0.15
	Random	12	0.38	0.07	4.37	0.28	0.71	0.00	2.21	0.20	2.83	0.25	1.61	0.15	1.54	0.14
ACFL658CREE-09	Relocation	19	0.21	0.05	4.23	0.32	0.71	0.00	3.25	0.38	2.68	0.10	1.55	0.09	1.12	0.11
	Random	19	0.35	0.10	3.58	0.36	0.71	0.00	2.99	0.30	3.01	0.11	1.57	0.10	1.25	0.12
ACFL699SMIT-09	Relocation	18	0.64	0.04	3.30	0.21	0.71	0.00	3.84	0.27	2.26	0.20	1.76	0.13	1.78	0.10
	Random	18	0.44	0.06	3.83	0.22	0.71	0.00	2.07	0.31	2.44	0.13	1.56	0.11	1.91	0.13
ACFL718TUTN-09	Relocation	16	0.47	0.08	5.31	0.35	0.71	0.00	5.56	0.42	3.01	0.32	1.37	0.11	1.34	0.13
	Random	15	0.45	0.08	4.76	0.28	0.88	0.17	5.02	0.56	2.94	0.31	1.55	0.10	1.64	0.14
ACFL739CAST-09	Relocation	20	0.32	0.06	4.74	0.26	0.89	0.13	3.53	0.39	2.63	0.16	1.58	0.15	1.52	0.12
	Random	20	0.24	0.04	4.88	0.22	0.84	0.10	2.81	0.35	2.88	0.19	1.55	0.16	1.65	0.15
ACFL759WOOD-09	Relocation	20	0.12	0.02	4.58	0.28	0.74	0.03	3.79	0.36	3.08	0.16	1.69	0.09	1.38	0.10
	Random	20	0.09	0.01	4.36	0.21	0.74	0.04	2.65	0.29	2.88	0.17	1.94	0.09	1.77	0.13

continued

Appendix E continued

Bird	Plot Type	N	% Honeysuckle Cover	SE	% Native Shrub Cover	SE	% Other Cover	SE	Stems 3-8 cm DBH	SE	Stems 8-23 cm DBH	SE	Stems 23-38 cm DBH	SE	Stems >38 cm DBH	SE
ACFL818CREE-09	Relocation	1	0.12	0.00	5.74	0.00	1.80	0.00	3.54	0.00	2.35	0.00	1.87	0.00	1.58	0.00
	Random	1	0.10	0.00	5.96	0.00	0.71	0.00	3.24	0.00	4.06	0.00	2.12	0.00	0.71	0.00
ACFL839SGAL-09	Relocation	16	0.09	0.01	4.92	0.21	0.83	0.12	4.10	0.20	3.47	0.18	2.26	0.07	1.14	0.10
	Random	17	0.07	0.00	4.72	0.18	0.82	0.12	4.06	0.27	3.66	0.18	1.88	0.13	1.20	0.12
ACFL859SUNB-09	Relocation	17	0.07	0.00	6.16	0.17	0.71	0.00	4.99	0.15	2.62	0.20	1.87	0.15	1.18	0.12
	Random	17	0.07	0.00	5.18	0.24	0.77	0.06	4.31	0.19	2.92	0.18	1.99	0.15	1.35	0.15
ACFL998CREE-08	Relocation	10	0.07	0.00	4.69	0.47	0.71	0.00	1.60	0.20	2.69	0.17	1.64	0.10	1.88	0.17
	Random	10	0.07	0.00	4.05	0.33	0.71	0.00	1.68	0.25	2.73	0.16	1.21	0.16	1.85	0.10



Appendix F:

Height of radio-tagged fledglings using Amur Honeysuckle (*Lonicera maackii*) and other  
plant species in central Ohio, 2008-2009

Bird	Plant	N	Mean Height (m)	SE
NOCA030CAST-09	Honeysuckle	2	2.00	0.00
	Other	4	6.25	2.10
NOCA071LOUN-09	Honeysuckle	3	1.67	0.67
	Other	1	1.00	0.00
NOCA151LOUS-09	Honeysuckle	12	2.50	0.26
	Other	8	5.38	1.46
NOCA191CREE-09	Honeysuckle	14	1.57	0.14
	Other	6	4.00	0.52
NOCA322ELKR-08	Honeysuckle	1	2.00	0.00
	Other	4	4.25	0.85
NOCA340RRN_-08	Honeysuckle	4	1.00	0.00
	Other	20	11.05	0.84
NOCA353TUTN-09	Honeysuckle	1	2.00	0.00
	Other	4	9.75	2.78
NOCA379TUTN-08	Honeysuckle	3	2.33	0.67
	Other	13	4.62	0.64
NOCA390WOOD-08	Honeysuckle	6	1.67	0.49
	Other	5	6.00	1.76
NOCA419CAST-08	Honeysuckle	2	2.50	0.50
	Other	2	5.50	0.50
NOCA440RRS_-08	Honeysuckle	8	2.50	0.46
	Other	3	5.33	1.33
NOCA471PRAI-08	Honeysuckle	5	2.20	0.49
	Other	16	5.50	0.60
NOCA472PRAI-09	Honeysuckle	4	1.75	0.48
	Other	20	3.05	0.48

continued

Appendix F continued

Bird	Plant	N	Mean Height (m)	SE
NOCA481PRAI-08	Honeysuckle	0	-	-
	Other	1	5.00	0.00
NOCA490PRAI-09	Honeysuckle	2	1.00	0.00
	Other	23	4.22	0.48
NOCA501ELKR-08	Honeysuckle	1	1.00	-
	Other	0	-	-
NOCA510LOUN-09	Honeysuckle	8	2.13	0.23
	Other	10	5.20	1.40
NOCA539TUTS-08	Honeysuckle	1	3.00	-
	Other	0	-	-
NOCA539WOOD-08	Honeysuckle	1	3.00	0.00
	Other	0	-	-
NOCA550RRN_-09	Honeysuckle	1	3.00	0.00
	Other	4	12.25	2.46
NOCA559LOUN-08	Honeysuckle	9	3.00	0.80
	Other	13	6.38	1.11
NOCA580CAST-08	Honeysuckle	5	2.60	0.68
	Other	0	-	-
NOCA590SGAL-09	Honeysuckle	1	2.00	0.00
	Other	21	5.00	0.79
NOCA600TUTS-08	Honeysuckle	13	2.62	0.37
	Other	8	6.38	1.44
NOCA620LOUS-08	Honeysuckle	6	2.00	0.37
	Other	9	7.33	1.56
NOCA630PUBH-09	Honeysuckle	7	1.71	0.18
	Other	18	4.17	0.47

continued

Appendix F continued

Bird	Plant	N	Mean Height (m)	SE
NOCA649CHER-09	Honeysuckle	0	-	-
	Other	23	2.83	0.42
NOCA671PUBH-08	Honeysuckle	6	1.83	0.48
	Other	15	3.20	0.34
NOCA730SGAL-09	Honeysuckle	2	2.00	0.00
	Other	23	3.78	0.30
NOCA790ELKR-09	Honeysuckle	7	2.43	0.20
	Other	14	5.14	0.75
NOCA829SGAL-09	Honeysuckle	4	2.00	0.00
	Other	15	5.33	0.89
NOCA850KENN-09	Honeysuckle	13	1.92	0.24
	Other	6	4.67	0.99

Bird	Plant	N	Mean Height (m)	SE
ACFL008CAMP-08	Honeysuckle	0	-	-
	Other	4	8.25	2.93
ACFL029BIGW-08	Honeysuckle	0	-	-
	Other	6	9.33	3.17
ACFL139TNC_-08	Honeysuckle	0	-	-
	Other	10	5.90	1.16
ACFL158NGAL-08	Honeysuckle	0	-	-
	Other	8	14.63	2.25
ACFL179PUBH-08	Honeysuckle	0	-	-
	Other	5	14.60	4.62

continued

Appendix F continued

Bird	Plant	N	Mean Height (m)	SE
ACFL199PUBH-08	Honeysuckle	1	1.00	-
	Other	5	12.00	4.56
ACFL217GALE-08	Honeysuckle	0	-	-
	Other	12	12.83	1.40
ACFL218CAST-08	Honeysuckle	0	-	-
	Other	9	6.00	0.47
ACFL258GIRL-08	Honeysuckle	2	4.00	2.00
	Other	6	8.50	3.55
ACFL298GARD-08	Honeysuckle	0	-	-
	Other	10	16.20	2.02
ACFL398CAST-08	Honeysuckle	0	-	-
	Other	1	4.00	-
ACFL477TNC_-09	Honeysuckle	0	-	-
	Other	14	7.64	1.09
ACFL478TNC_-08	Honeysuckle	1	2.00	-
	Other	15	7.13	0.80
ACFL498TNC_-09	Honeysuckle	1	2.00	-
	Other	12	7.25	1.26
ACFL518BIGW-09	Honeysuckle	3	2.00	0.58
	Other	14	7.71	1.29
ACFL538CREE-09	Honeysuckle	0	-	-
	Other	19	6.11	0.72
ACFL578PUBH-09	Honeysuckle	0	-	-
	Other	3	2.00	0.58
ACFL618TNC_-09	Honeysuckle	0	-	-
	Other	9	2.33	0.50

continued

Appendix F continued

Bird	Plant	N	Mean Height (m)	SE
ACFL638SMIT-09	Honeysuckle	0	-	-
	Other	12	5.42	0.36
ACFL658CREE-09	Honeysuckle	1	3.00	-
	Other	17	4.12	0.22
ACFL699SMIT-09	Honeysuckle	5	3.60	0.51
	Other	12	6.42	0.65
ACFL718TUTN-09	Honeysuckle	2	2.50	0.50
	Other	13	3.85	0.48
ACFL739CAST-09	Honeysuckle	0	-	-
	Other	13	7.62	0.81
ACFL759WOOD-09	Honeysuckle	0	-	-
	Other	19	9.37	0.71
ACFL818CREE-09	Honeysuckle	0	-	-
	Other	1	2.00	-
ACFL839SGAL-09	Honeysuckle	0	-	-
	Other	13	8.08	0.85
ACFL859SUNB-09	Honeysuckle	0	-	-
	Other	15	7.47	0.88
ACFL998CREE-08	Honeysuckle	0	-	-
	Other	10	7.90	0.86

### Appendix G:

Movement parameters for radio-tagged fledglings in central Ohio, 2008-2009

Bird ID	Dispersal Type	N	Natal HR (ha) 95% MCP	Natal HR (ha) 95% KDE	Natal HR (ha) 50% KDE	Dispersal Distance1 (m)	Dispersal Distance 2 (m)	Dispersal Distance 3 (m)
NOCA030CAST-09	Gradual	34	6429	12573	3538	272	-	-
NOCA151LOUS-09	Gradual	38	14530	27635	4712	569	-	-
NOCA191CREE-09	Abrupt	33	6795	10757	2338	349	-	-
NOCA340RRN -09	Gradual	47	14337	20093	4650	332	-	-
NOCA379TUTN-08	None	37	8398	15120	3407	-	-	-
NOCA390WOOD-08	Gradual	26	1768	3698	959	93	-	-
NOCA440RRS -08	Abrupt	30	3127	6320	1288	828	-	-
NOCA471PRAI-08	Abrupt	29	27371	44247	10811	209	-	-
NOCA472PRAI-09	Abrupt	37	13264	20524	4975	320	240	925
NOCA510LOUN-09	Gradual	24	6707	17610	3690	170	-	-
NOCA559LOUN-08	None	29	5412	12763	2796	-	-	-
NOCA590SGAL-09	None	44	10745	13149	3689	-	-	-
NOCA600TUTS-08	None	36	10686	19358	4576	-	-	-
NOCA620LOUS-08	None	37	7378	10376	2755	-	-	-
NOCA649CHER-09	Abrupt	35	7973	15587	3440	186	873	-
NOCA671PUBH-08	Gradual	38	4911	8221	1966	107	-	-
NOCA730SGAL-09	Gradual	34	9316	10679	1885	360	-	-
NOCA790ELKR-09	None	49	17787	25847	4265	-	-	-
NOCA829SGAL-09	None	40	3819	6237	1626	-	-	-
NOCA850KENN-09	Gradual	35	5805	10185	2341	163	-	-

continued



# Appendix G continued

Bird	Natal HR (ha)		Natal HR (ha)	
	95% MCP	N	95% MCP - Day 17	N
ACFL477TNC -09	26691	22	23927	17
ACFL478TNC -08	22863	21	22863	17
ACFL518BIGW-09	17943	22	13168	17
ACFL538CREE-09	13862	20	13862	17
ACFL658CREE-09	14892	20	14892	17
ACFL699SMIT-09	9923	19	8105	17
ACFL718TUTN-09	36719	17	36719	17
ACFL739CAST-09	19463	22	16584	17
ACFL759WOOD-09	20849	22	20603	17
ACFL839SGAL-09	19380	18	19380	17
ACFL859SUNB-09	7393	19	3732	17

## Appendix H:

Smoothing factors for kernel density estimation analyses of fledgling natal home ranges  
(area used prior to dispersal) in central Ohio 2008-2009

Bird	LSCVh	CVh	h ref
NOCA030CAST-09	6.766691	12.88899	14.37157
NOCA151LOUS-09	1.366868	17.672	26.75561
NOCA191CREE-09	6.850289	12.85897	12.56146
NOCA340RRN -09	11.14387	13.38976	21.47412
NOCA379TUTN-08	8.172653	12.1301	19.98376
NOCA390WOOD-08	8.15919	7.150763	9.069638
NOCA440RRS -08	8.473294	9.769427	9.964262
NOCA471PRAI-08	20.73618	19.92447	30.34517
NOCA472PRAI-09	8.757809	14.41156	19.55854
NOCA510LOUN-09	10.05651	17.62633	18.37865
NOCA559LOUN-08	14.26654	14.41185	14.07927
NOCA590SGAL-09	1.871167	9.498866	17.68985
NOCA600TUTS-08	13.29727	16.35889	16.19359
NOCA620LOUS-08	6.796783	9.311063	19.0106
NOCA649CHER-09	7.524311	16.75393	14.60914
NOCA671PUBH-08	4.150037	8.807492	14.26972
NOCA730SGAL-09	6.24108	9.174254	17.54673
NOCA790ELKR-09	5.903974	16.34419	23.91796
NOCA829SGAL-09	4.036174	8.406723	11.03735
NOCA850KENN-09	4.777428	10.76005	14.64102

#### Appendix I:

Variables used to explain variation in movement parameters of radio-tagged fledglings in central Ohio, 2008-2009.

Habitat variables are expressed as the mean with standard error.

N: Number of vegetation survey plots.

Bird	N	Honeysuckle Cover	SE	% Native Shrub Cover	SE	Stems 3-8 DBH	SE	Territory Density	Fledging Day (Julian)	Energetic Condition	Urban Index
NOCA030CAST-09	5	37.00	9.46	8.85	3.82	14.40	0.81	3.50	129	0.05	1.25
NOCA151LOUS-09	19	41.36	5.26	14.79	1.89	20.11	2.60	3.50	133	-2.41	1.26
NOCA191CREE-09	15	60.50	4.01	8.07	1.33	29.33	3.48	2.50	135	0.39	-0.71
NOCA340RRN_-08	24	12.76	3.46	11.90	2.99	21.21	1.45	3.00	153	-0.73	0.75
NOCA379TUTN-08	16	5.67	4.47	53.44	4.64	15.56	2.79	2.25	157	3.19	1.61
NOCA390WOOD-08	13	35.92	4.71	22.92	2.63	7.69	1.30	1.50	206	-3.18	0.32
NOCA440RRS_-08	12	52.69	7.33	13.63	3.64	27.25	6.23	3.75	213	-4.15	0.75
NOCA471PRAI-08	20	11.19	3.16	25.65	4.16	15.65	2.09	2.00	153	1.54	-1.12
NOCA472PRAI-09	23	8.25	1.71	12.18	1.35	35.13	5.25	1.50	157	-0.46	-1.12
NOCA510LOUN-09	15	55.53	4.86	12.17	1.46	13.00	2.53	2.50	143	-0.59	1.26
NOCA559LOUN-08	16	60.48	5.48	8.02	1.29	18.19	2.61	2.25	208	1.88	1.26
NOCA590SGAL-09	23	3.35	0.86	21.14	1.71	12.13	1.38	1.75	175	4.77	-0.57
NOCA600TUTS-08	17	48.38	4.38	21.31	3.53	25.59	3.08	4.50	156	-0.95	1.61
NOCA620LOUS-08	16	30.32	3.74	13.77	1.98	15.38	1.74	3.75	166	2.60	1.26
NOCA649CHER-09	23	0.72	0.10	36.34	2.95	15.91	2.22	3.50	146	0.19	0.76
NOCA671PUBH-08	19	33.64	5.07	27.45	4.70	30.21	2.92	2.00	181	-1.61	-1.15
NOCA730SGAL-09	23	4.26	1.20	20.35	1.63	14.39	1.08	1.75	153	-1.47	-0.57
NOCA790ELKR-09	24	33.51	3.81	14.90	1.30	15.04	1.24	6.25	191	-0.97	-0.16
NOCA829SGAL-09	19	23.17	5.29	19.79	5.36	22.00	1.54	1.75	193	0.40	-0.57
NOCA850KENN-09	20	29.79	2.14	17.99	1.18	15.15	2.64	3.75	190	1.53	0.89

continued

Appendix I continued

Bird	N	% Honeysuckle Cover	SE	Stems 3-8 DBH	SE	Stems >8 DBH	SE	Energetic Condition	Urban Index
ACFL477TNC_-09	20	18.48	3.98	45.35	2.78	27.05	1.48	-0.37	-0.96
ACFL478TNC_-08	19	6.63	1.81	13.74	2.06	23.16	1.80	0.11	-0.96
ACFL518BIGW-09	19	9.21	4.24	18.63	3.59	13.42	1.07	0.53	1.31
ACFL538CREE-09	19	0.00	0.00	2.79	0.55	10.68	0.83	0.26	-0.71
ACFL658CREE-09	19	7.33	3.21	12.68	3.04	9.84	0.65	-0.35	-0.71
ACFL699SMIT-09	18	35.58	3.71	15.44	2.07	11.00	1.34	0.00	-0.28
ACFL718TUTN-09	16	25.81	5.90	33.00	4.49	13.25	2.43	0.11	1.61
ACFL739CAST-09	20	13.88	3.87	14.80	2.73	11.40	0.74	0.18	1.25
ACFL759WOOD-09	20	1.58	0.84	16.35	2.83	13.60	0.92	-0.12	0.32
ACFL839SGAL-09	16	0.33	0.17	16.94	1.58	17.63	1.35	-0.65	-0.57
ACFL859SUNB-09	17	0.00	0.00	24.76	1.44	11.47	1.49	-0.37	-0.42