

# Temporal variation in the consequences of an exotic shrub on avian nest predation

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ABSTRACT.-: Exotic plants are recognized as serious threats to biodiversity due to their tendency to disrupt ecosystem processes and alter floristic composition. Recent work also shows exotic plants can influence predator-prey interactions. For example, birds nesting in exotic shrubs such as *Lonicera maackii* (Amur honeysuckle) and *Rosa multiflora* (multiflora rose) in urbanized areas are more likely to have their nests depredated than if they nested in native substrates. However, no studies have evaluated whether or not this increased vulnerability to predation varies temporally over the course of a breeding season. Increased predation is especially likely early in the season given that certain exotics, such as *Lonicera*, show advanced leaf phenology and exhibit full leaf flush long before most other nesting substrates are available to breeding birds. This study tested if the risk associated with nesting in native substrates and two common exotic shrubs varied temporally across the breeding season for a common abundant understory nesting bird, the Northern Cardinal (*Cardinalis cardinalis*). Logistic exposure models were used to estimate daily nest survival rates of 607 cardinal nests found in riparian forests in central Ohio in 2001-2005. An information-theoretic approach was used to evaluate 4 *a priori* models explaining variation in daily nest survival. Results indicate that julian date and substrate type (native, *Lonicera* or *Rosa*) interacted to influence nest survival. Daily survival rates increased throughout the breeding season for nests in native substrates and *Lonicera*, whereas daily survival of nests located in *Rosa* remained more stable throughout the season. Although nests in *Rosa* were generally more vulnerable to predation than nests in *Lonicera*, season influenced relative vulnerability. Nests in *Lonicera* in early spring, prior to leaf emergence of co-dominant plants, showed the lowest rates of daily nest survival of all substrates. Understanding temporal variation in risk

to nest predation may elucidate the mechanisms that determine effects of exotic plants on breeding birds.

## CHAPTER 1

### LITERATURE REVIEW

Invasive exotic plants have been a large focus of research and management due to their ability to greatly alter ecosystem form and function (Bazzaz 1986) and even shaping prey-predator relationships (Borgmann & Rodewald 2004; Remes 2003; Schmidt & Whelan 1999). Although a number of hypotheses have been suggested to explain the apparent increase vulnerability faced by birds nesting in exotics, little empirical evidence is available to evaluate competing hypotheses (Schmidt & Whelan 1999; Borgmann & Rodewald 2004).

Several studies have shown exotic plants may promote high densities of early nesting birds due to advanced leaf phenology. Returning Blackcaps (*Sylvia atricapilla*) during spring migration used the early leaf flush of exotic black locust trees as an early nesting cue, causing a significant increase in nest density in contrast to surrounding landscapes (Remes 2003). Similarly, Leston and Rodewald (2006) results supported understory structure and exotic stems best explained breeding cardinal abundance. Vegetation density is often a quality cue as it aids in concealment from predators (Martin 1993; Mills et al. 1989; Kershner et al. 2001), however Martin and Roper (1988) suggested that total number of nest sites has a greater impact on predation risk. Early leaf flush may lead to density dependent predation risk due to a less number of available nest sites and substrates for predators to search, increasing search efficiency (Wilcove 1985; Keyser et al. 1998; Schmidt and Whelan 1998; Niemuth and Boyce 1995; Remes 2003). The objective of this study was to further examine possible interactions between temporal variation and daily survival of nests located in three

different substrate types: (i) native, (ii) *Lonicera*, and (iii) *Rosa* across the entire nesting season.

## LITERATURE REVIEW

Preventing and mitigating invasions by exotic plants has become a formidable issue for both scientists and managers (Usher 1988, Usher et al. 1988, Soule 1990, Westman 1990). The number of species involved, the scale of the problem, and an increasing acceleration of invasions pose a huge threat to ecosystem integrity (Hobbs & Humphries 1995; Cowie and Werner 1993). Although it is common knowledge that invasive species can shape ecosystems at many scales, including nutrient and carbon cycling, plant and wildlife community structures (Bazzaz 1986; Gould & Gorchov 2000; Collier et al. 2002; Woods 1993; Luken 1988), scientists have a relatively poor understanding of the characteristics of invaders that drive these changes.

Among the most problematic invasive woody plants in the eastern United States is *Lonicera maackii* [Rupr.] Maxim. (Amur honeysuckle). Originally introduced to North America as an ornamental from northeastern Asia in 1896, *Lonicera* has invaded 24 eastern U.S. states and Ontario (Luken & Thieret 1996). Within Ohio, *Lonicera* spread from the initial introduction site in Hamilton County to 34 other counties of Ohio in less than 30 years. Studies have identified a variety of characteristics making this species, and others sharing its genus, a formidable invader: structural plasticity (Luken 1988), extended leaf phenology (Trisel 1997), mutualistic relationships with seed dispersers (Richardson et al. 2000), high reproductive output (Luken & Mattimiro 1991), low level of herbivory (Trisel & Gorchov 1994), and damaged tissue regeneration (Luken 1990). Since its introduction, the invasive

*Lonicera* has spread from cultivated fencerows to forest edges and open pastures (Braun 1961).

The impact of *Lonicera* on ecosystems poses a serious threat to native biodiversity, especially for plants. Research supports the presence and percent cover of *Lonicera* negatively affect tree seedling density and species richness, as well as herbaceous species richness and percent-cover (Woods 1993; Hutchinson & Vankat 1997). The ability of *Lonicera* to negatively impact surrounding plant communities arises partly from its growth form, as its overarching branches limit sunlight reaching the forest floor (Hutchinson & Vankat 1997). *Lonicera* also may inhibit growth of nearby plants with secondary compounds. Indeed, Dorning and Cipollini (2006) observed that *Lonicera* root and leaf extracts inhibited of herbaceous seed germination with no autotoxic effects. Some of the experimental treatments supported these extracts could also promote seed germination of *Lonicera*. Retarding seed germination greatly alters population demography, and Gould and Gorchov (2000) supported an indirect relationship between total fitness for 3 forbaceous species, *Galium aparine*, *Impatiens pallida*, and *Pilea pumila*, and the presence of *Lonicera maackii*.

Exotic invasive plants, such as *Lonicera maackii*, have been shown to impact wildlife, especially birds, as well as plant communities (Borgmann and Rodewald 2004; Remes 2003; Schmidt and Whelan 1999). Schmidt and Whelan (1999) first demonstrated exotic plants could influence avian nesting success, and they reported greater nest predation in exotic plants *Lonicera* spp. and *Rhammus* spp in contrast to native substrates. Borgmann and Rodewald (2004) also found even after accounting for distance to edge, nests placed in *Lonicera* faced a greater risk of predation in comparison to native substrates. Interestingly,

this pattern persisted only in urban landscapes, suggesting that landscape-scale factors (e.g., predator communities or nest site density) may be important contributors to the pattern.

Although some studies have shown that *Lonicera* may increase risk of predation to avian nests, the causes of this vulnerability are unclear (Schmidt and Whelan 1999; Borgmann and Rodewald 2004). Predation risk may be greater because of (1) plant architecture, which can reduce nest height (Borgmann and Rodewald 2004) and/or facilitate predator access, (2) density of nesting substrates and/or nests, (3) early leaf flush (Schmidt and Whelan 1999; Borgmann and Rodewald 2004), and (5) sampling artifact.

Site selection and nest placement can directly impact nest survival and the overall fecundity of a bird through their relationship with predator efficiency (Martin & Roper 1988; Filliater et al. 1994; Schmidt et al. 2005). There has been a variety of hypotheses explaining the relationship between nest placement at the substrate and patch scales and predation risk. Schmidt et al. (2005) observed the relationship between nest site selection in an exotic plant, Japanese barberry (*Berberis thunbergii*), and Veery (*Catharus fuscescens*) nest success. It suggested that nest success was partially due to increased nest height and deterring thorns that coincide with selection of the exotic barberry over ground nesting. Filliater et al. (1994) examined eight possible different mechanisms driving the relationship between cardinal nest site and predation, but ultimately concluded that there may be no predictably “safe” nest sites in systems with diverse predator communities. However, the study did not take substrate type into account.

Avian nest density has a direct relationship with predation risk due to an increase in predator search efficiency (Wilcove 1985; Niemuth and Boyce 1995; Keyser et al. 1998; Schmidt and Whelan 1998; Remes 2003). Predator search efficiency increases in landscapes

or patches with greater nest densities though search effort may decrease as predators create search images (Niemuth & Boyce 1995). Keyser et al. (1998) found a greater predator activity level surrounding clustered artificial nests; an increase in available resources for predators decreases their foraging efforts. Limited search area coupled with an increase in local predator activity level increases nest predation risk (Martin 1988). Increased nest densities may be due to limited available substrates with high quality cues, such as number of available nest sites and vegetation density.

The advanced leaf phenology of exotic plants impacts early season nesting cues for birds (Remes 2003; Schmidt & Whelan 1999) and early nest densities (Remes 2003). Remes (2003) observed early leaf flush attracting early spring migrant Blackcaps (*Sylvia atricapilla*) to nest earlier in introduced black locust plantations than surrounding native riparian habitats at the expense of their nest survival rates. This process led to a relative greater nest density in the plantations. Many birds choose dense vegetated habitats and substrates to reduce their probability of predation (Martin 1993; Martin 1988). Early leaf flush of limited substrates may pose as an ecological trap early in the nesting season (Gates & Gysel 1978) as predation risk has been observed to be higher earlier in the nesting season (Best & Stauffer 1980; Schmidt 1999) and when nests are at greater densities. Remes (2003) suggested this increase in density attributed to observed elevated nest predation of Blackcaps early on in the nesting season.



## CHAPTER 2

Temporal variation in the risk of nest predation for native and exotic nesting substrates.

### INTRODUCTION

Exotic invasive plants can significantly impact ecosystem function and structure shaping both plant and wildlife communities (Bazzaz 1986; Gould & Gorchov 2000; Collier et al. 2002; Woods 1993; Luken 1988). Exotic plants can have deleterious effects on avian reproductive success at the substrate and patch level (Lloyd & Martin 2005; Remes 2003; Schmidt & Whelan 1999; Ortega et al. 2006; Scheiman et al. 2003), often because exotics can alter predator prey interactions. Schmidt and Whelan (1999) first examined the impacts of exotic shrubs, *Lonicera maackii* (Amur honeysuckle) and *Rhamnus cathartica*. (common buckthorn) on nesting success, and suggested that exotic nesting substrates may be ecological traps for birds who prefer them. Borgmann and Rodewald (2004) furthered this research by establishing the importance of the landscape has on predator-prey relations and the impacts of invasive exotics plants. Proposed mechanisms behind this increase in predation include plant architecture, nest placement within a patch, nest placement within a substrate, increase in nest density in exotics caused by leaf phenology, and lack of thorns (Schmidt & Whelan 1999; Remes 2003). In addition, advanced leaf phenology of exotics may lead to density dependent predation if predators increase their foraging activity or efficiency in response to

unusually high densities of nests early in the breeding season (Keyser et al. 1998; Niemuth & Boyce 1995; Schmidt et al. 2005). Indeed, Remes (2003) observed that early leaf flush of introduced black locusts led to an increase in density of Blackcaps in contrast to the surrounding bare native landscapes and, potentially, to elevated rates of nest predation. However, no studies have explicitly examined exotic shrub phenology as a potential mechanism of increased vulnerability to nest predation (Schmidt et al. 2005, Borgmann & Rodewald 2005).

Using the Northern cardinal (*Cardinalis cardinalis*) as a focal species, I examined temporal variation in the daily survival rate of understory nests in three common nesting substrates (native plants, *Lonicera maackii*, and *Rosa multiflora*). I hypothesized that the higher predation rates of nests observed in *Lonicera maackii* resulted from the advanced phenology (i.e., early leaf flush) of the species, which induced birds to nest earlier in the season and increased predator efficiency by reducing the diversity of nest locations and possibly increasing nest density within patches of exotics. Northern Cardinal was an appropriate focal species as it is abundant in the study area and nests in understory vegetation ranging from 1 to 3.5 meters preferring to nest in thickets, dense shrubs, or saplings (Ehrlich et al. 1988; Borgmann & Rodewald 2005; Leston & Rodewald 2006). Northern cardinals are permanent residents of central Ohio, and they prefer more urbanized landscapes (Leston 2005). They are multibrooded, laying up to five clutches in a season (Filliater et al. 1994) providing a large nest sample size. Northern cardinals have shown preference to nesting in exotic shrubs, such as *Lonicera sp.* (honeysuckle) and *Rosa multiflora* (multiflora rose) more

than native substrates (Fillater et al. 1994; Leston & Rodewald 2006). Fillater et al. (1994) had 79 of their 121 cardinal nests (65%) built in these two invasive exotic shrubs.

## METHODS

*Study Sites*--Fourteen riparian forest stands were studied within the urbanizing landscapes of the Scioto River Watershed in central Ohio (ca. 40N 00' 83W 00'). All sites were located in mature riparian forest of approximately 100 to 200 meters in width and  $\geq 250$  m length and along rivers in approximately 20 to 40 m in width. Archetypal dominant trees in this riparian habitat included eastern cottonwood (*Populus deltoides*), silver maple (*Acer saccharinum*), sugar maple (*Acer saccharum*), boxelder (*Acer negundo*), and hackberry (*Celtis occidentalis*) (Leston & Rodewald 2006). The understory was dominated by overstory seedlings and saplings, but also included understory species such as dogwood (*Cornus sp.*), hawthorn (*Crataegus sp.*), spicebush (*Lindera benzoin*) and paw paw (*Asimina triloba*). The most common invasive exotic shrubs were Amur honeysuckle (*Lonicera maackii*) and multiflora rose (*Rosa multiflora*).

*Nest Monitoring*— Nests were located during the cardinal breeding season from April through September 2001-2005. A variety of cues were used to locate nests and these included behavioral cues, such as adults visiting the nest, carrying nest material and/or food, and vocalizations near the nest (e.g., alarm calls, begging calls). Nests were monitored every 2-3 days through either successful completion or until failure. At each nest visit, the status (active, not active) was recorded. I classified nests as being placed in native shrubs, saplings, or trees (hereafter termed “native”), *Lonicera*, *Rosa multiflora*, or “other” substrates

including vine tangles and dead debris. Nests placed in other species of exotic plants, which were relatively uncommon in the study area, were not considered for analysis.

*Nest Survival Analysis*—Data were pooled across years 2001 through 2005 for the entire study area. A logistic exposure model (Shaffer 2004) was used to estimate daily nest survival rates. This method was appropriate for analysis as it improves upon older methods of nest survival analysis (Mayfield 1961, 1975; Aebischer 1999). Although the Mayfield method (1961) accounts for the fact different exposure periods of nests may affect survival estimates, the method is limited because it assumes a constant daily survival rate of nests between nest-check intervals and among nests throughout the season. Thus, the Mayfield method fails to account for confounding variables impacting nest success, which limits its usefulness in identifying important factors explaining nest success (Shaffer 2004). The logistic exposure model allows for varying visitation intervals, does not make assumptions on when nest loss occurs, and it can be coupled with information theoretic approach for multiple model analysis (Shaffer 2004).

*Model Analysis*—Current statistical analysis of data has shifted from hypothesis testing to model selection and parameter estimation to better explain biological processes (Shaffer 2004). The logistic exposure method of nest survival estimation coupled with an information theoretic technique, Akaike's information criterion (AIC), were used to analyze four *a priori* models to observe their impact on daily nest survival. The four *a priori* models evaluated were (1) julian date, (2) substrate (native, *Lonicera*, or *Rosa*), (3) julian date and substrate, and (4) the interaction between julian date and substrate type. AIC was used to rank the models; the model with the lowest AIC score indicates its better explanatory power. Differences in AIC scores reflect the relative rankings of models, with  $\Delta AIC = 0$  indicating

the highest ranked model and a  $\Delta\text{AIC} < 2$  indicates equal plausibility. Akaike's weight ( $w$ ) shows the weight of evidence for a particular model. PROC GENMOD was used in SAS to find the log-likelihoods for each *a priori* model and their AIC scores.

## RESULTS

A total of 607 Northern Cardinal understory nests (2657 nest-check intervals) were monitored from 2001 through 2005 nesting seasons. Of these nests 36.2% were in native substrates, 40.9% in *Lonicera*, and 22.9% were in *Rosa*. Nests located in native substrates had a mean daily survival rate of  $0.96 \pm 0.00049$  SE, while nests in *Lonicera* and *Rosa* experienced a mean daily survival rates  $0.95 \pm 0.0016$  SE and  $0.94 \pm 0.000027$  SE, respectively. Over the typical Northern cardinal 21-day nesting cycle, these daily survival rates approximately translate to 42%, 34%, and 30% nest success for nests in native, *Lonicera*, and *Rosa* respectively (Fig. 1).

I evaluated the evidence for 4 *a priori* models representing alternate hypotheses explaining variation on daily nest survival rates (DSR): (1) julian date, (2) substrate type, (3) julian date and substrate type, and (4) julian date, substrate type, and their interaction (Table 1). The highest ranked model ( $\Delta\text{AIC} = 0$ ) included julian date, substrate type and their interaction. The Akaike weight of evidence ( $w_i = 0.719$ ) indicates that there is a 72% chance this model is actually the true or best model to explain variation observed in DSR. No alternate models were closely ranked ( $\Delta\text{AIC} > 3.00$ ) (Table 1). Predicted DSRs derived from top model showed that DSR increased throughout the season for native plants and *Lonicera*, but not for the nests located in *Rosa* (Fig. 2).

Furthermore, early in the season prior to julian date 160, daily survival rate for nests in *Lonicera* was greatly lower than those in the other two substrates (Fig. 2). Interestingly,

DSR in *Lonicera* surpassed that seen in native substrates approximately around julian date 160 which corresponds roughly to the time of season when full leaf flush of all potential nest substrates is complete (i.e. early June).

I performed *a posteriori* tests to evaluate two possible causes of this apparent shift in DSR and used julian date as 160 as the divider between early and late season. I was particularly interested in how relative vulnerability of nests in *Lonicera* and native substrates was related to nest height as well as the distribution of nests among the three substrate types. Nest height was significantly greater for nests in native versus exotic substrates (Full Model:  $F_{5,600} = 79.36$ ,  $P < 0.0001$ . Substrate:  $F_{2,603} = 101.27$ ,  $P < 0.001$ ), but this pattern was influenced by season as well. Over the breeding season, nest height significantly increased (Season:  $F_{1,604} = 15.94$ ,  $P < 0.001$ , Substrate\*Season:  $F_{2,603} = 5.14$ ,  $P = 0.0061$ ) by approximately 1.5m for nests in native substrate and 0.4m for nests in *Lonicera* but not for nests in *Rosa*. Using each forest stand as a replicate, the proportion of nests located in various substrates in early versus late season increased by 2.3 times for native substrates ( $F_{1,27} = 13.06$ ,  $P = 0.0013$ ), decreased by 3 times for *Rosa* ( $F_{1,26} = 8.46$ ,  $P = 0.0073$ ), but did not differ for nests in *Lonicera* ( $F_{1,26} = 0.55$ ,  $P = 0.4630$ ) or other substrates ( $F_{1,26} = 0.04$ ,  $P = 0.8411$ ) (Fig. 4).

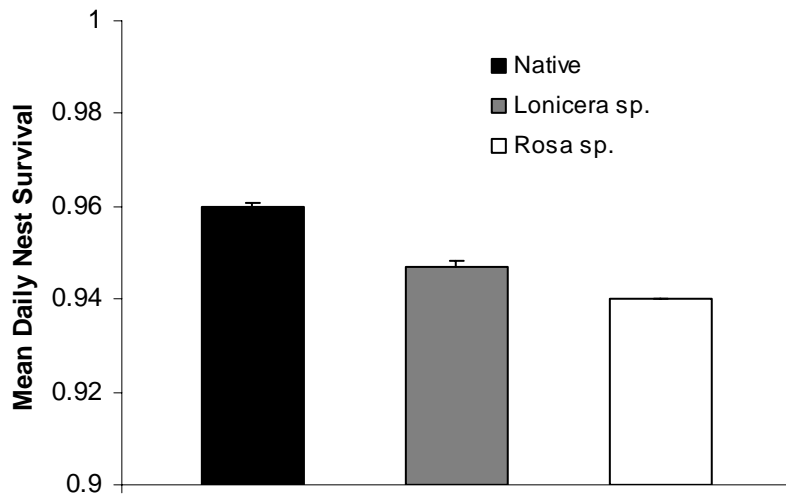


Fig 1.—Mean daily nest survival for Northern Cardinal nests located in native (n = 220), *Lonicera sp.* (n=248), and *Rosa multiflora* (n=139) in central Ohio, 2001-2005.

Table 1: Results from information-theoretic approach to evaluate the relative performance of *a priori* models explaining daily nest survival of Northern Cardinal nests in central Ohio, 2001-2005.

Model	Log-likelihood ratio	K	AIC	$\Delta AIC$	$w_i$
julian   substrate	-481.03	5	972.06	0.00	0.719
julian	-484.57	3	975.14	3.08	0.154
julian substrate	-483.77	4	975.54	3.48	0.126
substrate	-489.21	3	984.42	12.36	0.001

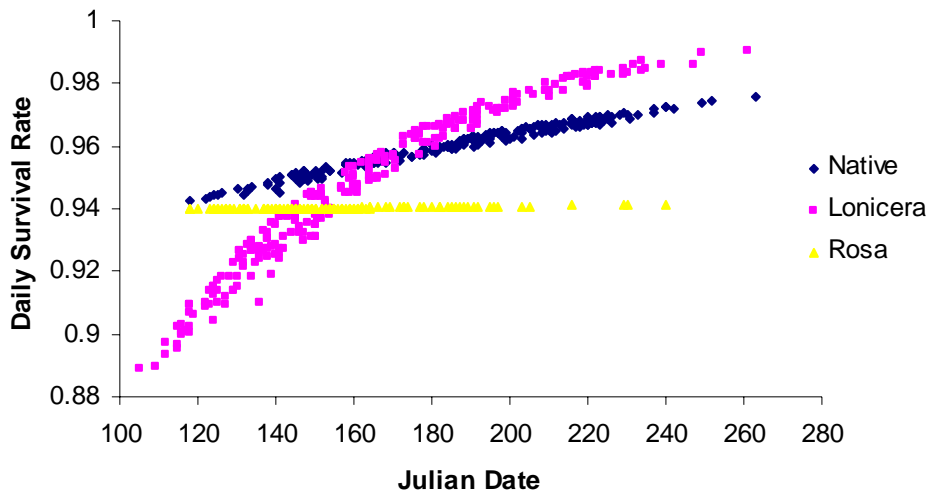


Fig 2.—Relationship between daily survival rate and julian date for Northern Cardinal nests located in three different substrate types, native (n = 220), *Lonicera sp.* (n=248), and *Rosa multiflora* (n=139) throughout the nesting season in central Ohio, 2001-2005.

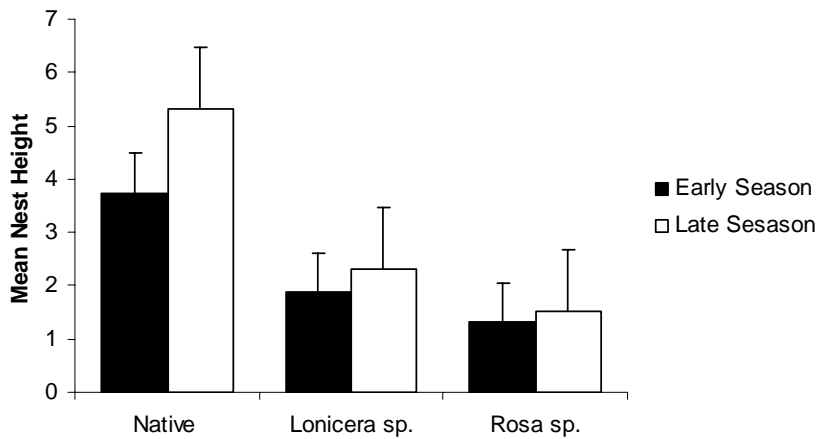


FIG 3.—Change in mean Northern Cardinal nest height between early (julian date <160) and late (julian date > 160) portions of the nesting season for nests in three substrates: native (n = 220), *Lonicera sp.* (n=248), and *Rosa multiflora* (n=139) in central Ohio, 2001-2005.



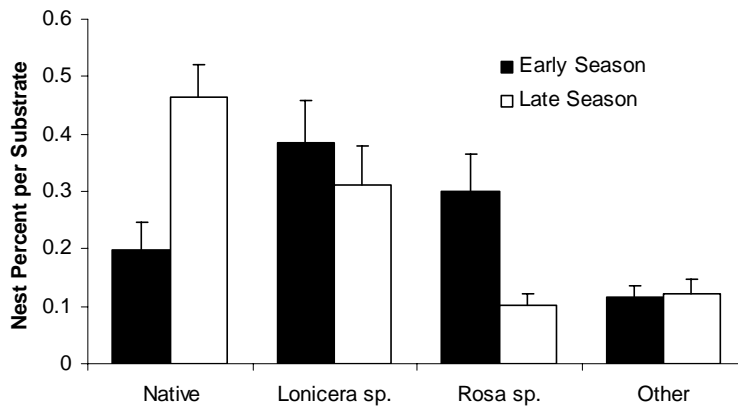


Fig 4.—Percent of Northern Cardinal nests in each substrate for native (n = 220), *Lonicera sp.* (n=248), and *Rosa multiflora* (n=139) and contrasting between early (<160 julian date) and late (>160 julian date) portions of the nesting season in central Ohio, 2001-2005.

## DISCUSSION

Differences in daily survival rates (DSR) of nests between those in exotic and native substrates were not uniform across the season. Although nests located in the two common exotic substrates, *Lonicera* and *Rosa*, had lower overall nest survival rates than nests in native substrates, risk of predation was greatest in *Lonicera* early in the season, corresponding to the period prior to widespread leaf emergence in the forest stand (approximately julian date 160). During this “early season”, the modeled daily nest survival rate for nests in *Lonicera* was extremely low, beginning with an approximate daily survival rate of 89%, which translates to an abysmal 8.7% chance of survival over a 21-day nesting cycle. Much later in the season, however, nest survival rates in *Lonicera* improved dramatically. This temporal change in nest survival rates provides evidence for the hypothesis that advanced leaf phenology may be a mechanism underlying the increased vulnerability to predation in some exotic substrates.

These findings of temporally variable predation risk are consistent with past studies that show greater predation risk occurs early in the nesting season and in the incubation cycle as well (Mahoney et al. 2006; Dinsmore et al. 2002; Filliater et al 1994). An increase in predation early in the season may be due to behavioral changes in predators or structural changes in the habitat (e.g., vegetation density and nest concealment). Interestingly, our findings support a seasonal increase in DSR for nests located in *Lonicera* and native substrates, but not for those occurring in *Rosa*.

Differences in nest height among the three substrates probably contributed to differences in predation risk because lower nests may be more accessible to a greater range of predators. Indeed, DSRs were lowest for the nests closest to the ground (*Rosa*), and greatest for those placed higher within the understory placed within native substrates. Similarly, the increase in DSR corresponds to the increase in nest height over the nesting season. Filliater et al. (1994) results observed a similar relationship between nest height, temporal variation, and daily survival rate. Daily survival rates increased as the season progressed as well did the height of the nests placed within the substrates as well as the understory strata. The study suggested that an increase in height correlated with an increase in concealment of the nest. Nest placement can directly impact nest survival (Kershner et al. 2001; Filliater et al. 1994; Martin & Roper 1988). However, differences in nest height fail to explain why daily survival rates of nests in *Lonicera* changed so dramatically over the season, eventually surpassing the DSR of those in the native substrates.

Our findings suggest that seasonal changes in distribution of nests among substrates may better explain temporal patterns in DSR. Nest predation was greatest for exotic substrates in the early spring when 68% of all nests were located in either *Lonicera* or *Rosa*.

Nests located in native substrates during this period represented <20% of all nests, and had the greatest chance of survival. As the season progressed, the proportion of nests in native substrates, including those in substrates designated as “other” such as vine tangles and dead substrates, rose to >58%, and the DSR concomitantly declined for these substrate types and improved for nests in *Lonicera*. This diversification of nesting substrate likely prompted a decrease in nest density within any given stratum, which may have reduced predator search efficiency caused by higher nest densities (Wilcove 1985; Niemuth and Boyce 1995; Keyser et al. 1998; Schmidt and Whelan 1998; Remes 2003). Indeed, Keyser et al. (1998) found a greater predator activity level surrounding clustered artificial nests; an increase in available resources for predators increases their foraging efforts. Niemuth and Boyce (1995) found a similar increase in nest predation correlated with higher nest densities of sage grouse.

The advanced phenology of *Lonicera* likely contributed to the pattern of depredation observed in this study (Remes 2003, Schmidt & Whelan 1999). Remes (2003) observed that early spring migrant Blackcaps (*Sylvia atricapilla*) preferred to nest in introduced black locust plantations with advanced leaf phenology rather than the surrounding bare native riparian habitats. This process of choosing substrates with early leaf flush may ultimately act to homogenize early season nest sites and/or vertically compress nests into a narrower band of forest strata than available for nesting later in the season. Lack of diversity of nest sites can lead to increase nest predation (Martin 1993). Early in the nesting season, this study observed a greater nest percentage in exotic substrates with advanced leaf phenology than bare native substrates. However, as the native substrates flushed later in the season, diversity of nesting substrates and nest heights increased.

If advanced leaf phenology guides, in part, the extent to which exotic substrates act as ecological traps early in the nesting season, then ecologists may be able to predict which exotic plants may be most likely to negatively affect breeding birds, and consequently better target control or restoration effects. These findings also suggest that the negative consequences of exotic shrubs may be most acute for species nesting early in the breeding season, such as resident and short-distant migrant birds. For example, many long-distant migrants may arrive in breeding areas after leaf emergence is well underway in all strata, possibly buffering them from increased vulnerability to predation. Ultimately, effective conservation and requires that researchers move beyond documenting the impacts of exotic plant invasions, and identify underlying mechanisms that drive ecosystem and community-level consequences.

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LITERATURE CITED – Lauren be sure to double check that all listed refs are cited and all cited are listed. Thanks!

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