# THE EFFECTS OF LOGGING ON SUCCESS OF ACADIAN FLYCATCHER (*EMPIDONAX VIRESCENS*) NESTS IN YELLOWWOOD STATE FOREST, INDIANA

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ABSTRACT.--High edge density resulting from selective logging may increase losses of nests to various predators and elevate brood parasitism by Brown-headed Cowbirds (*Molothrus ater*). We measured the effects of logging on survival and parasitism of Acadian Flycatcher (*Empidonax virescens*) nests in Yellowwood State Forest, a deciduous forest in south-central Indiana, in 1995 and 1996. Four tracts were logged between these two breeding seasons, using individual and group selection techniques. Four other sites were controls. Daily survival rate during the egg stage was higher at treatment sites than at control sites in 1995. Nestling-stage survival was low in both conditions (treatment and control) in 1995. In 1996, egg-stage survival was high in both conditions. Nestling-stage survival was lower at logged sites than at control sites. Overall success rate of nests increased from 1995 to 1996 at control sites, but was similar at treatment sites before and after logging. Cowbird parasitism decreased from 1995 to 1996 at control sites, but was similar at treatment sites before and after logging. If factors responsible for between-year variation operated similarly in both conditions, the observed interaction effects of year and condition may indicate logging decreases breeding success. Alternatively, site-specific processes at control tracts may have caused higher success in 1996. Longer-term studies, with measurements for several years before and after logging, are necessary to understand how timber extraction affects avian breeding success. Of particular interest are effects on declining bird populations and on species restricted to regenerating forest.

DATA FROM THE North American Breeding Bird Survey indicate that a number of species of Neotropical migrant birds have experienced population declines in recent decades (Sauer and Droege 1992, Peterjohn et al. 1995, Sauer and Link 2002, Sauer et al. 2003). It is unclear whether this represents a general phenomenon, since there are other species of Neotropical migrants that have increased in number over the past few decades (James and McCulloch 1995, James et al. 1996). The determination of a cause for a decline of any given species is hindered by the possibility that explanations may involve factors that operate in any of the three components of these species' ranges: breeding (e.g. Sherry and Holmes 1992, Böhning-Gaese et al. 1993), wintering (e.g. Rappole and McDonald 1994), and migratory stopovers (e.g. Moore and Simons 1992). This contribution focuses on factors operating on the breeding grounds.

Breeding productivity, and thus population dynamics, of migrant birds may be affected by both the loss (decrease in total area) and fragmentation (decrease in contiguity) of breeding habitat. Decreased availability of habitat will decrease the number of breeding territories and thus directly reduce population-level productivity. The extent to which productivity is reduced will depend in part on the relationships among habitat availability, population density, territory size, and individual productivity (Fretwell 1972, Hixon 1980). Decreased territory size will not fully compensate for the loss of habitat, since territory size is unlikely to increase in proportion to area lost indefinitely (Huxley 1934, Zimmerman 1971, Fretwell 1972, Hixon 1980).

Broad-scale habitat fragmentation has been shown to reduce breeding success of forest-nesting birds in the Midwestern United States (Robinson et al. 1995). Fine-scale fragmentation may also influence avian reproductive success through the effects of habitat edges (Gates and Gysel 1978, Paton 1994, Winslow 1999). An edge between two habitats may reduce avian breeding success by reducing pairing success of males (Van Horn et al. 1995, Burke and Nol 1998, Ortega and Capen 1999), increasing levels of nest predation by various predators (e.g. Gates and Gysel 1978; Whitcomb et al. 1981; Chasko and Gates 1982; Brittingham and Temple

1983; Wilcove 1985; Paton 1994; Fenske-Crawford and Niemi 1997; Bourque and Villard 2001; Flaspohler et al. 2001a, 2001b; Ford et al. 2001; Huhta and Jokimaki 2001), increasing levels of brood parasitism by Brown-headed Cowbirds (*Molothrus ater*, e.g. Gates and Gysel 1978, Chasko and Gates 1982, Brittingham and Temple 1983, Winslow et al. 2000, Ford et al. 2001), and by decreasing food availability (Burke and Nol 1998).

The specific effects of edges on nest predation may vary regionally as a function of the habitat choices of the predators at hand (Hannon and Cotterill 1988, Winslow 1999). There are many animal species which may prey on nests in the forests of the Midwestern United States. Important Midwestern nest predator species that occur in high abundance near forest edges include Blue Jays (*Cyanocitta cristata*), rat snakes (*Elaphe obsoleta*), and raccoons (*Procyon lotor*).

Techniques used for extracting timber from public and private forests can increase edge density. Evidence from a number of nesting studies indicates that logging reduces avian breeding success (Fenske-Crawford and Niemi 1997; Morse and Robinson 1999; Winslow et al. 2000; Robinson and Robinson 2001; Bourque and Villard 2001; Flaspohler et al. 2001a, 2001b; Huhta and Jokimaki 2001), but few studies have measured success before and after timber extraction (but see Clawson et al. 2002, Gram et al. 2003). Furthermore, some researchers have failed to find consistent negative effects of logging on breeding success (e.g. Duguay et al. 2001, Gram et al. 2003).

*Variation in nesting success over the course of a season*.--There exists substantial variation in nest survival and cowbird parasitism over various scales of space and time. It is difficult to assign a portion of this variation to the effects of forest management activities without examining all the sources of variation. Nest success and brood parasitism can be quite different among sites or among years at the same site. One of the most significant sources of variation may be variation over time within the course of a given field season. In temperate forests nest density varies greatly over the course of a breeding season, increasing quickly at the beginning and peaking before the middle of the season. Predation levels in some systems are high early in the season but much lower late in the season (Gottfried and Thompson 1978, Nolan 1978, Wilson and Cooper 1998). Within-season variation is important to study because it constitutes a large portion of the existing variation, it provides a baseline with which to evaluate the effects of logging and other forms of vegetative disturbance, and it is essential to consider when estimating seasonal fecundity. Late-season nesting, and the ability of birds to raise multiple broods, are especially important in this regard.

*History of nest survival analysis*.--Ornithologists who measure nesting success typically monitor every nest that is discovered and can be easily monitored. For this reason samples are never random and are subject to many potential biases. Mayfield (1961, 1975) introduced a method to estimate nesting success while correcting for one such bias. Because successful nests are active for longer than unsuccessful nests, they are more likely to be discovered by researchers and tend to be over-represented in samples. Success rate calculated as proportion of nests that are successful will overestimate the true success rate.

The Mayfield method corrects for this bias by calculating daily nest survival based on the length of time that nests are monitored. One records the number of days each nest is active and known to researchers (“exposure-days”) during each nest stage (i.e. laying, incubation, and nestling) and the number of nests lost in each stage. One calculates daily survival rate as the proportion of exposure days (for all nests in the sample summed) on which a nest survived (i.e. *daily survival rate = 1 - losses/exposure*). This statistic is the maximum likelihood estimator of the probability a nest will survive a given day (Hensler and Nichols 1981). Raising the daily survival rate calculated for a given nest stage by the exponent of the number of days necessary to complete that stage yields an estimate of the probability that a given nest will survive that stage. Overall success rate (i.e. the probability a given nest will survive from clutch initiation to fledging) can then be estimated as the product of the estimated probabilities of success for all stages.

Because daily survival rate is the proportion of days in which a nest survived, many researchers treat nest survival statistics as frequency data, where the exposure-day is the sampling unit. Some investigators have used a contingency table approach (e.g. Holmes et al. 1992). Hensler and Nichols (1981) devised a *Z*-test to compare nest survival rates and used simulations to show that this method performed well with samples of ≥20 nests.

Sauer and Williams (1989) introduced a procedure to contrast survival rates based on recapture and recovery data. This procedure was widely adopted by researchers studying nest success after Hines and Sauer (1989) developed a software program named CONTRAST to perform the necessary calculations. The input parameters for the program are survival rate and standard error. Because users must calculate standard errors before running CONTRAST, it is not clear that this method is easier to use for nesting studies than statistical packages that perform contingency table analysis. Perhaps the appeal among students of nest success is the ability to test multiple hypotheses through planned contrasts.

There seem to be a number of weaknesses to the approach of treating exposure days as frequency data. Because the exposure-day is considered the sampling unit, days from the same nest are not independent. This may thus be considered a type of pseudo-replication. Furthermore, the time interval seems arbitrary--one could just as easily consider hours or minutes to be sampling units.

For these reasons our research group has chosen to use resampling analysis to compare nest survival rates (Ford et al. 2001). The general approach is to pool nests from all samples, with associated exposure and loss data, and randomly draw nests with replacement from the total data set to produce 10,000 (or so) simulated data sets. Next one calculates the parameter of interest from each simulated data set and compares the observed parameter to the distribution of simulated parameters to determine the probability that a value equal to or more extreme than the observed value would be drawn from the simulated distribution.

The advantages of a resampling approach are that the nest is the sampling unit, it is easy for the investigator to understand what the results show, it is possible to perform a test on any parameter that can be calculated, there is a minimal set of assumptions, and it is possible to examine interaction effects.

We first presented this resampling approach in an analysis of the effects of an agricultural corridor on nest survival (Ford et al. 2001). In that study we calculated Mayfield statistics for seven breeding bird species, pooled among years. For each species, we pooled data for two sites (a site adjacent to an agricultural corridor and an interior forest site) to generate 10,000 simulated data sets. We did this separately for the egg (laying plus incubation) and nestling stages. For each simulated data set, we calculated the difference in daily survival rate between the two sites. We then compared the observed difference in daily survival rate to the distribution of simulated differences. In this contribution we employ a similar approach, although the parameters examined differ somewhat.

*Objectives*.--We designed an experiment to evaluate the effects of logging in Yellowwood State Forest, a deciduous forest in south-central Indiana, on nest survival and cowbird parasitism level. State foresters mark timber in Indiana state forests using individual and group selection techniques. Private logging contractors remove individually marked trees from within a harvest tract, and typically create several small “regeneration openings” where foresters have demarcated groups of trees. Site preparation, entailing the construction and maintenance of roads, skid trails, and log landings, results in additional disturbance. These methods generate high edge density and may thus increase the abundance and/or activity of nest predators and cowbirds (Winslow 1999).

For this reason one might hypothesize that the extraction of timber from state forests decreases avian nest survival (by increasing predation) and increases cowbird parasitism. Here we test the following predictions of this hypothesis: (1) nest survival is lower in forest sites that have recently been logged than in similar tracts that have not been logged, (2) cowbird parasitism is higher in forest sites that have recently been logged than in similar tracts that have not been logged, (3) birds breeding in forest tracts that have recently been logged experience lower nest survival after harvest than before harvest, and (4) birds breeding in forest tracts that have recently been logged experience higher cowbird parasitism after harvest than before harvest.

We chose the Acadian Flycatcher (*Empidonax virescens*) as a focal species to monitor. This species breeds in mature forest throughout the eastern United States and winters in Central and South America (Whitehead and Taylor 2002). The nests are suspended from the outer branches of trees, usually saplings near streams or watercourses, and generally easy to locate and monitor. Breeding Bird Survey data indicate the global population has been quite stable, but abundance of this species has declined in Indiana from 1966-2002 (Sauer et al. 2003). Acadian Flycatchers avoid breeding in small forest tracts and can be highly parasitized in fragmented landscapes (Robbins et al. 1989). Investigating the effects of habitat modification on the demography of this widespread and abundant species may aid efforts to understand the implications of forest management for rarer species, often more difficult to study and of higher conservation relevance.

## METHODS

*Field methods*.--We employed a crew of field assistants to measure survival and parasitism of nests in eight tracts in Yellowwood State Forest from late April through early September in 1995 and 1996 (Table 1, Fig. 1). Observers varied in their prior field experience. DEW rotated among all sites, training and aiding the other observers. Logging contractors extracted timber from four tracts between these two breeding seasons, cutting trees that state foresters had marked using individual and group selection techniques. Four other sites were controls. We attempted to locate all Acadian Flycatcher nests within these tracts, and also monitored nests of other species. We examined the contents of each nest every third day, using mirrors mounted on extendable poles. We attempted to determine the fate of each nest, and how many host and/or cowbird young fledged.

We included nests known to be active and low enough to be monitored with a mirror for analysis. We excluded nests whose fates were clearly affected by observers. We attempted to assign fates to all other nests, although the fates of some nests were uncertain. We pooled nests among all four sites within each condition (treatment and control).

*Analysis of variation in predation within a season*.--We examined variation in nest abundance and nest predation over the course of one field season (1995) in order to evaluate the importance of within-season variation in the absence of logging, and to investigate the relationship between nest abundance and predation level. We evaluated the hypothesis that predation is higher during peak nesting than later in the season by testing the prediction that daily predation rate is higher for early Acadian Flycatcher nests than for later nests of that species.

We performed a bootstrap resampling technique to test this prediction, using the Resampling Stats software package (Resampling Stats 1999). We drew nests randomly with replacement from the 1995 data set to generate 10,000 simulated samples of early and late nests, calculated the difference in daily predation rate for each pair of simulated samples to generate a distribution of differences, and compared the observed difference in daily predation rate with confidence bounds of the simulated distribution.

*Analysis of effects of logging on nest survival*.--In order to understand the effects of timber extraction on nest survival, we resampled nest survival data calculating three different odds ratios; (1) the ratio of overall success rate of Acadian Flycatcher nests from 1996 to overall success rate for 1995 for all sites pooled, (2) the ratio of overall success rate from cut sites to overall success rate from uncut sites for both years pooled, and (3) the ratio of the cut-to-uncut ratio for 1996 to the cut-to-uncut ratio for 1995. The extent to which this last odds ratio deviates from one indicates the magnitude of the interaction effect between year and treatment, and thus the effect of timber extraction.

In order to perform the resampling analysis to evaluate the interaction effect, we generated 10,000 simulated data sets with samples for each combination of year and treatment. For each simulated data set, we calculated the odds ratio of overall success rate in cut sites to uncut sites for both years. We then calculated (for each simulated data set) the ratio of the odds ratio for 1996 to the odds ratio for 1995 and compared the observed ratio of ratios to the distribution of simulated ratios of ratios.

*Analysis of effects of logging on brood parasitism*.--In order to examine the effect of timber extraction on cowbird parasitism we employed contingency table analysis, with year and condition as independent variables and frequency of parasitized Acadian Flycatcher nests as the dependent variable (SYSTAT 1992). We compared log-likelihood ratio statistics ($G$) to critical values of the $\chi^2$ distribution. The extent to which the three-way interaction varies from values expected assuming independence indicates the magnitude of the effect of logging.

## RESULTS

*Variation in nesting success over the course of a season*.--In 1995 we monitored nests of 19 species. Reproductive statistics for these species are shown in Table 2. Predation levels tended to be higher during peak nesting than later in the season when nest abundance was lower. To demonstrate this we used the number of monitorable nests of all species known to be active each day among all sites during 1995 as an index of nest abundance.  We plotted this index of nest abundance over the course of the season (Fig. 2).  Figure 2 also shows the proportion of nests depredated each day during the season.  The peak in nest predation occurred a week or two after the peak in nest abundance (Fig. 2).  (High values of predation toward the end of the season probably reflect variability resulting from low sample sizes.)

The number of Acadian Flycatcher nests known to be active each day followed a phenological pattern similar to that for all species pooled, though beginning later in the season and with more pronounced bimodality (Fig. 3).  Proportion of Acadian Flycatcher nests preyed upon showed peaks a week or two after the peaks in flycatcher nest abundance (Fig. 3).  We classified flycatcher nests into early (clutch initiated before 19 June) and late (clutch initiated after 18 June) nests.  Daily predation rate was higher for early nests than for late nests (Table 3).  Bootstrap analysis showed that this difference was statistically significant during the nestling stage, but not during the egg stage (Table 3).

*Effects of timber extraction on nest survival*.--In 1995, daily survival rate of nests during the egg stage was higher at treatment sites than at control sites (Table 4, Fig. 4A).  Nestling-stage daily survival rate was low at both sets of sites in that year (Table 4, Fig. 4B).  In 1996, egg-stage daily survival rate was high at both sets of sites (Table 4, Fig. 4A).  Nestling-stage daily survival rate was lower at sites that were logged than at control sites (Table 4, Fig. 4B) in 1996.  Daily survival rate in treatment sites was similar before and after logging (Figs. 4A, B).

Overall success rate of nests increased from 1995 to 1996 at control sites, but was similar at treatment sites before and after logging (Table 5, Fig. 5).  Resampling analysis indicated a statistically significant interaction effect of year and treatment on overall success rate (Table 6).

*Effects of timber extraction on cowbird parasitism*.--Table 7 presents cowbird parasitism data for the eight tracts monitored in Yellowwood in 1995 and 1996. Cowbird parasitism decreased from 1995 to 1996 at control sites, but was similar at treatment sites before and after logging (Fig. 6). Although parasitism was similar at treatment and control sites in 1996, loglinear analysis shows a statistically significant interaction effect of year and condition on parasitism frequency ($G = 3.49$, df = 1, one-sided $P = 0.031$).

## DISCUSSION

The hypothesis that state forest logging decreases nest survival is supported by the observation that nestling-stage survival and (as a consequence) overall success rate were higher in the control sites than the logged sites in 1996 (Table 4, Table 5, Figs. 4 and 5). However, the prediction that nest survival at the treatment sites would decrease after logging did not hold. Brood parasitism was 67% higher at the logged sites than at the control sites in 1996, although the difference is not statistically significant (Table 7, Fig. 6). Brood parasitism did not increase at the treatment sites after timber was cut.

If factors responsible for between-year variation operate similarly in both sets of sites, the observed interactions between year and treatment may indicate timber extraction decreases breeding success. Alternatively, site-specific processes at control tracts may have caused higher success in 1996. For instance, the site with the largest sample of Acadian Flycatcher nests, Shaw's Hollow, was a control site. However, this site experienced much lower nest survival in 1995 than in 1996. Overall success rate of Acadian Flycatcher nests at this site in 1994 was

0.316, similar to the value estimated in 1995 (Table 4). It is unknown why success was so much higher at this site in 1996 than during the first two years, but the large sample of nests monitored at this site heavily influenced the overall pattern. If we exclude data from Shaw's Hollow, overall success rate at the other control sites was similar between 1995 (0.207) and 1996 (0.239).

There is no particular reason to exclude this or any other site, but this thought experiment indicates that processes specific to one site may shape the overall pattern observed when nests are pooled across sites. A superior approach would be to monitor a large number of sites in each category and treat the site as the sampling unit, but logistical constraints prohibited this.

Almost all published studies that examine the effects of timber extraction on nesting success only present data from after the disturbance. It is illustrative to consider how we might interpret the results of this study if we only examine the data from 1996, after the logging. Acadian Flycatchers breeding in the sites that had been cut experienced lower nest survival and higher cowbird parasitism than those in the uncut sites. We might regard this as convincing evidence that timber extraction reduces avian breeding success, were it not for the data from 1995. This demonstrates the importance of monitoring nesting success in multiple seasons, before and after habitat disturbances.

One other study, the Missouri Ozark Forest Ecosystem Project, (MOFEP) has published nest success data from seasons before and after timber extraction (Clawson et al. 2002, Gram et al. 2003). In this study, as in our own, interannual variation within control sites obscured interpretation of results. The MOFEP investigators suggest that the logging at experimental sites may have affected breeding densities at control sites in their study. We do not believe that the control sites in Yellowwood were affected by the logged sites in our own study, because we did not choose control sites adjacent to treatment sites. Every year logging occurs at a number of tracts throughout Yellowwood, and 1995 and 1996 were fairly typical in this regard.

The MOFEP investigators did not find statistically significant effects of logging on nest success with the analytic techniques they employed (Clawson et al. 2002, Gram et al. 2003). The estimated effect sizes they report are, however, in some cases substantial. For some species the timber extraction may have decreased nest success; for other species logging may have increased success. For the Acadian Flycatcher the MOFEP data suggest a negative effect of clear-cutting, but not of the uneven-aged treatment comparable to the Yellowwood management strategy.

In order to understand with confidence the effects of timber extraction on the breeding success of forest birds, it will be necessary to undertake long-term and broad-scale monitoring programs. Nest success should be monitored at multiple sites for several years before and many years after timber extraction. The patterns observed may be specific to the species and landscapes studied. For this reason, it is desirable to adopt a mechanistic approach; i.e. to understand why and not simply whether edge effects occur (Winslow 1999).

Whether or not logging affects nest success, the dramatic variation in nest predation and parasitism within and among breeding seasons suggests that there may be other factors more strongly influencing success. Varying weather patterns may differentially affect food availability and predator behavior (Sillet et al. 2000, Morrison and Bolger 2002). It may be fruitful to examine between-season variation in patterns of within-season variation in nest abundance and success.

Abundant species such as the Acadian Flycatcher are useful for exploring mechanisms of edge effects, but it is also critical that we obtain information on the effects of forest management activities on rare and declining species. The Cerulean Warbler (*Dendroica cerulea*), although widespread and locally abundant, has experienced declining population trends since the inception of the Breeding Bird Survey (Link and Sauer 2002, Sauer et al. 2003). Low breeding densities, combined with a tendency to nest high in the canopy, make this species a challenging subject for nesting studies. A natural experiment in the form of an ice storm of historic magnitude granted Jones et al. (2001) the opportunity to compare reproductive success of Cerulean Warblers before and after habitat disturbance. They observed a dramatic decrease in fledging success during the breeding season after the storm, with a slight rebound the succeeding year.

Cerulean Warblers are more abundant in Yellowwood State Forest than in much of the surrounding forested landscape. Breeding success in the forests of south-central Indiana is high, for the species that have been studied, relative to more fragmented sites throughout the Midwest (Robinson et al. 1995). This landscape may harbor source populations of many species of Neotropical migrants. Most of Yellowwood State Forest is actively logged with short-rotation selective techniques, and it is important to understand how these practices affect the breeding success of Cerulean Warblers and other declining bird species.

It should be noted that several species of migrant birds whose populations are declining use regenerating forest for nesting and may benefit from the canopy disturbance that results from timber extraction (Gram et al. 2003). It is important to study how logging affects the abundance and breeding success of these species. Three issues are especially relevant in this regard: (1) What were the historical abundances and distributions of these species? (2) Do canopy gaps and regenerating patches increase the number of breeding territories for certain bird species or merely alter their spatial distribution? and (3) Do individuals breeding in or near management openings suffer lower breeding success as a result of increased nest predation and brood parasitism?

*Recommendations for management*.--There is significant variation in nesting success both spatially and temporally (within and among breeding seasons). In this study we found that year (before or after treatment) and condition (treatment or control) interacted to influence survival and parasitism of Acadian Flycatcher nests, but it is not clear whether these patterns resulted from the timber extraction or from other sources of variation that differed between the sets of sites assigned to each condition. Public forest managers should limit logging where productivity of forest interior migrant birds is a priority until we better understand the factors influencing spatio-temporal variation in nesting success. Where logging does occur, researchers should use the opportunity to monitor nesting success before and after the disturbance.

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TABLE 1. Eight tracts in Yellowwood State Forest that were monitored in 1995 and 1996. Timber was extracted from Treatment sites between the two breeding seasons; Control sites remained unlogged.

| Site name | Site code | Compartment | Tract | Condition |
| --- | --- | --- | --- | --- |
| Dubois Ridge | DU | 6 | 3 | Control |
| Lanam Ridge | LR | 8 | 1 | Control |
| Shaw's Hollow | SH | 1 | 16 | Control |
| White Ridge | WR | 10 | 10 | Control |
| Ferris West | EX | 1 | 1 | Treatment |
| Mossop Ridge | MR | 2 | 15 | Treatment |
| Scarce'o'fat | SF | 9 | 10 | Treatment |
| Yellowwood Lake | YL | 7 | 20 | Treatment |

TABLE 2. Reproductive statistics for nests of 19 species monitored in Yellowwood State Forest (all sites combined) during 1995. Length of exposure (when nests were active and being monitored) summed for all nests is shown for the egg and nestling stages. Daily survival rate (DSR) is calculated as 1 - losses/exposure.

| | Number | Proportion | Egg Stage | | Nestling Stage | | Proportion |
|---|---|---|---|---|---|---|---|
| Species | of nests | fledged | Exposure (days) | DSR | Exposure (days) | DSR | parasitized |
| Yellow-billed Cuckoo (*Coccyzus americanus*) | 1 | 0.00 | 4.5 | 0.78 | 0 | 1.00 | 0.00 |
| Whip-poor-will (*Caprimulgis vociferus*) | 1 | 0.00 | 8.5 | 0.88 | 0 | 1.00 | 0.00 |
| Ruby-throated Hummingbird (*Archilochus colubris*) | 2 | 0.00 | 10.5 | 0.81 | 0 | 1.00 | 0.00 |
| Acadian Flycatcher (*Empidonax virescens*) | 135 | 0.36 | 1541 | 0.97 | 812.5 | 0.95 | 0.11 |
| White-eyed Vireo (*Vireo griseus*) | 1 | 0.00 | 9.5 | 0.89 | 0 | 1.00 | 0.00 |
| Blue-headed Vireo (*Vireo solitarius*) | 1 | 0.00 | 12.5 | 0.92 | 0 | 1.00 | 0.00 |
| Red-eyed Vireo (*Vireo olivaceus*) | 21 | 0.24 | 167.5 | 0.96 | 81 | 0.88 | 0.57 |
| Carolina Chickadee (*Poecile carolinensis*) | 2 | 1.00 | 0 | 1.00 | 15 | 1.00 | 0.00 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Wood Thrush (*Hylocichla mustelina*) | 24 | 0.38 | 169 | 0.94 | 132 | 0.96 | 0.25 |
| Gray Catbird (*Dumetella carolinensis*) | 2 | 0.50 | 9.5 | 1.00 | 12.5 | 0.92 | 0.00 |
| Worm-eating Warbler (*Helmitheros vermivorus*) | 26 | 0.81 | 134 | 0.99 | 141.5 | 0.97 | 0.46 |
| Ovenbird (*Seiurus aurocapillus*) | 13 | 0.46 | 67 | 0.94 | 44.5 | 0.93 | 0.46 |
| Louisiana Waterthrush (*Seiurus motacilla*) | 4 | 0.50 | 19.5 | 0.95 | 13.5 | 0.93 | 0.25 |
| Kentucky Warbler (*Oporornis formosus*) | 2 | 1.00 | 0 | 1.00 | 2 | 1.00 | 0.00 |
| Hooded Warbler (*Wilsonia citrina*) | 19 | 0.53 | 101.5 | 0.95 | 81 | 0.95 | 0.47 |
| Scarlet Tanager (*Piranga olivacea*) | 1 | 1.00 | 9 | 1.00 | 11.5 | 1.00 | 1.00 |
| Eastern Towhee (*Pipilo erythrophthalmus*) | 2 | 0.50 | 21.5 | 1.00 | 16 | 0.94 | 0.00 |
| Northern Cardinal (*Cardinalis cardinalis*) | 8 | 0.63 | 45 | 1.00 | 46 | 0.93 | 0.00 |
| Indigo Bunting (*Passerina cyanea*) | 6 | 0.33 | 49.5 | 0.94 | 24.5 | 0.96 | 0.17 |

TABLE 3. Daily predation rate of Acadian Flycatcher nests in 1995 in eight tracts in Yellowwood State Forest in the egg and nestling stages. Early clutches were initiated before 19 June and late clutches were initiated after 18 June. The difference in daily predation rate between early and late nests was outside bootstrap confidence bounds for the nestling stage but not for the egg stage.

| | | Egg Stage | | Nestling Stage | |
|---|---|---|---|---|---|
| | | Early Nests | Late Nests | Early Nests | Late Nests |
| No. of Nests | | 81 | 51 | 50 | 42 |
| Exposure (days) | | 992.5 | 548.5 | 368 | 444.5 |
| Predations | | 28 | 10 | 30 | 12 |
| Daily Predation Rate | | 0.0282 | 0.0182 | 0.0815 | 0.0270 |
| Difference | | 0.0100 | | 0.0545 | |
| Bootstrap Confidence Bounds | | | | | |
| | 97.50% | 0.0151 | | 0.0331 | |
| | 95% | 0.0125 | | 0.0274 | |
| | 90% | 0.0098 | | 0.0213 | |

TABLE 4. Survival rate of Acadian Flycatcher nests in Yellowwood State Forest. Timber was cut in four sites between 1995 and 1996; the other four sites remained unlogged. Length of exposure (when nests were active and being monitored) summed for all nests is shown for the egg and nestling stages. Number of nests lost is also shown. Daily survival rate (DSR) is calculated as 1 - losses/exposure. Overall success rate (OSR) is calculated as $DSR(egg)^{16} * DSR(nestling)^{13}$.

| | Before logging (1995) | | | | | | | | After logging (1996) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Site | No. of nests | Exposure days (egg) | Losses (egg) | DSR (egg ) | Exposure (nestling) | Losses (nestling) | DSR (nestling) | OSR | No. of nests | Exposure days (egg) | Losses (egg) | DSR (egg ) | Exposure (nestling) | Losses (nestling) | DSR (nestling) | OSR |
| Unlogged | | | | | | | | | | | | | | | | |
| DU | 11 | 123.5 | 5 | 0.96 | 42.5 | 4 | 0.91 | 0.14 | 8 | 75 | 3 | 0.96 | 42.5 | 1 | 0.98 | 0.38 |
| LR | 9 | 96.5 | 3 | 0.97 | 59.5 | 1 | 0.98 | 0.48 | 11 | 83.5 | 5 | 0.94 | 53 | 2 | 0.96 | 0.23 |
| SH | 36 | 462.5 | 11 | 0.98 | 235.5 | 12 | 0.95 | 0.35 | 36 | 511.5 | 3 | 0.99 | 370.5 | 6 | 0.98 | 0.74 |
| WR | 13 | 69.5 | 9 | 0.87 | 30 | 1 | 0.97 | 0.07 | 3 | 38 | 1 | 0.97 | 14 | 1 | 0.93 | 0.25 |

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Subtotal | 69 | 752 | 28 | 0.96 | 367.5 | 18 | 0.95 | 0.28 | 58 | 708 | 12 | 0.98 | 480 | 10 | 0.98 | 0.58 |
| Logged | | | | | | | | | | | | | | | | |
| EX | 13 | 183.5 | 4 | 0.98 | 71 | 4 | 0.94 | 0.33 | 18 | 178.5 | 6 | 0.97 | 65 | 8 | 0.88 | 0.11 |
| MR | 10 | 120.5 | 4 | 0.97 | 59.5 | 2 | 0.97 | 0.37 | 15 | 174 | 1 | 0.99 | 126.5 | 4 | 0.97 | 0.60 |
| SF | 17 | 195.5 | 1 | 1.00 | 133 | 8 | 0.94 | 0.41 | 22 | 271.5 | 4 | 0.99 | 154 | 8 | 0.95 | 0.39 |
| YL | 26 | 289.5 | 6 | 0.98 | 181.5 | 11 | 0.94 | 0.32 | 24 | 265.5 | 8 | 0.97 | 120.25 | 7 | 0.94 | 0.28 |
| Subtotal | 66 | 789 | 15 | 0.98 | 445 | 25 | 0.94 | 0.35 | 79 | 889.5 | 19 | 0.98 | 465.75 | 27 | 0.94 | 0.33 |
| Total | 135 | 1541 | 43 | 0.97 | 812.5 | 43 | 0.95 | 0.31 | 137 | 1597.5 | 31 | 0.98 | 945.75 | 37 | 0.96 | 0.44 |

TABLE 5. Overall success rate of Acadian Flycatcher nests in eight tracts in Yellowwood State Forest. Timber was extracted from treatment tracts between the 1995 and 1996 breeding seasons.

| | 1995 | 1996 | Pooled |
|---|---|---|---|
| Control | 0.284 | 0.579 | 0.414 |
| Treatment | 0.347 | 0.326 | 0.336 |
| Pooled | 0.314 | 0.435 | 0.373 |

TABLE 6. Resampling analysis of overall success rate of Acadian Flycatcher nests in Yellowwood State Forest. Alpha levels are shown for the main effect of year, the main effect of condition (treatment or control), and the interaction effect between year and treatment. Alpha levels were determined by comparing observed odds ratios to confidence limits of bootstrapped values (see text).

| Comparison | Alpha (two-sided) |
|---|---|
| 1996 to 1995 | $0.05 < p < 0.10$ |
| Treatment to Control | $p > 0.20$ |
| Interaction Effect | $p < 0.05$ |

TABLE 7. Cowbird parasitism data for Acadian Flycatcher nests in eight tracts in Yellowwood. Four tracts ("T") were logged between the 1995 and 1996 breeding seasons. Four other sites ("C") remained unlogged. Cowbird eggs per nest is calculated using all nests (parasitized and unparasitized) found before hatch.

| Site | Pre-logging (1995) | | | | Post-logging (1996) | | | |
|---|---|---|---|---|---|---|---|---|
| | Number of nests | Proportion Parasitized | Nests found before hatch | Cowbird eggs per nest | Number of nests | Proportion Parasitized | Nests found before hatch | Cowbird eggs per nest |
| C | | | | | | | | |
| DU | 10 | 0.000 | 10 | 0.000 | 8 | 0.125 | 7 | 0.143 |
| LR | 9 | 0.444 | 8 | 0.500 | 10 | 0.000 | 9 | 0.000 |
| SH | 31 | 0.065 | 31 | 0.065 | 34 | 0.059 | 34 | 0.059 |
| WR | 12 | 0.417 | 12 | 0.667 | 3 | 0.000 | 3 | 0.000 |
| | 62 | 0.177 | 61 | 0.230 | 55 | 0.055 | 53 | 0.057 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| T | | | | | | | | |
| EX | 13 | 0.154 | 13 | 0.154 | 17 | 0.235 | 16 | 0.250 |
| MR | 10 | 0.000 | 10 | 0.000 | 12 | 0.083 | 10 | 0.100 |
| SF | 16 | 0.125 | 16 | 0.125 | 18 | 0.056 | 17 | 0.059 |
| YL | 25 | 0.000 | 23 | 0.000 | 19 | 0.000 | 18 | 0.000 |
| | 64 | 0.063 | 62 | 0.065 | 66 | 0.091 | 61 | 0.098 |
| Total | 126 | 0.119 | 123 | 0.146 | 121 | 0.074 | 114 | 0.079 |

FIG. 1. Map of nest monitoring plots in Yellowwood State Forest. See Table 1 for site codes.

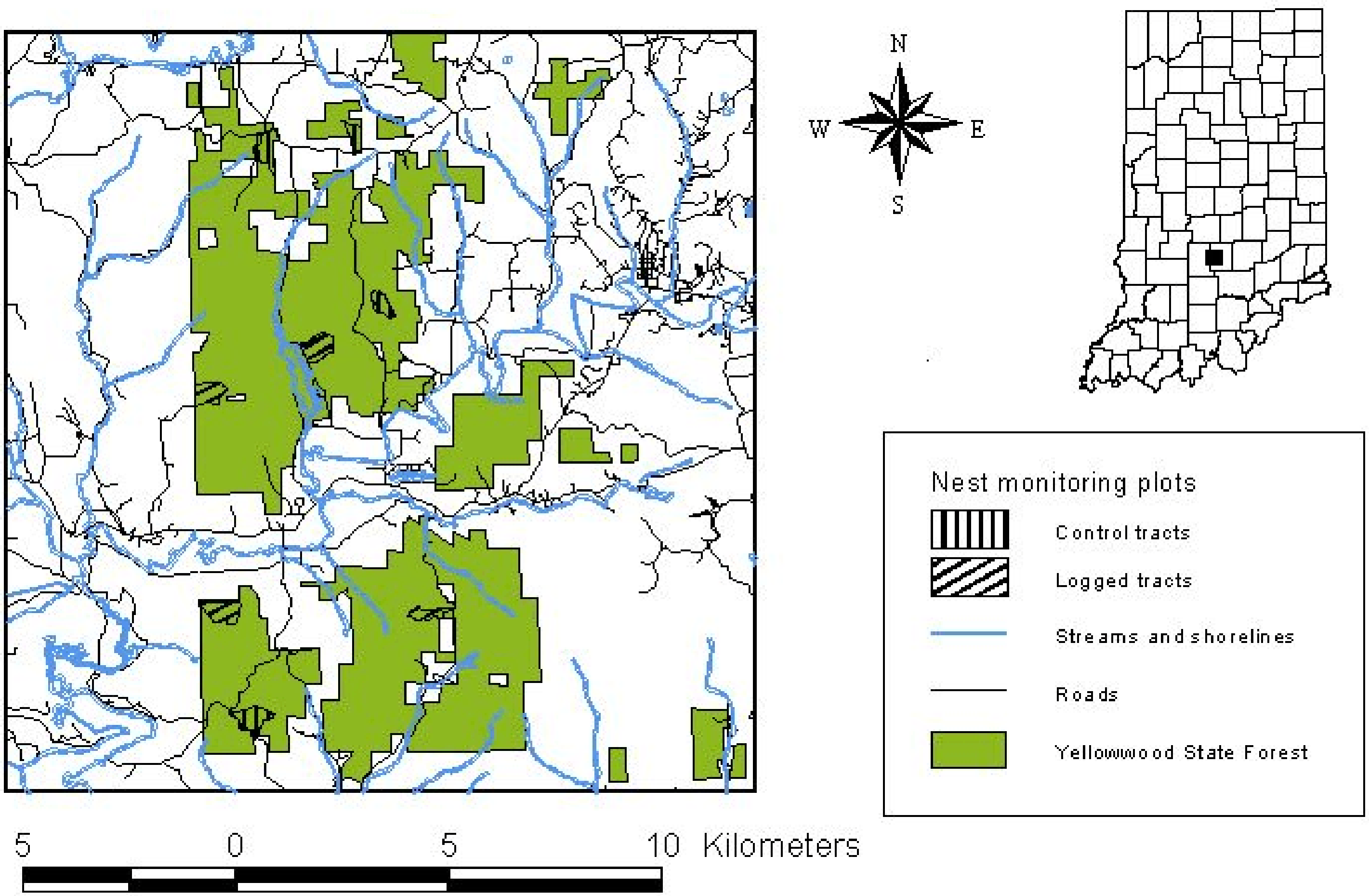
FIG. 2. Number of nests known to be active and monitorable each day in 1995 in eight tracts in Yellowwood State Forest, pooling all species. Also shown are the percentage of nests taken by predators on each day. Early and late portions of the season are divided by 19 June, which is the date when nest abundance stabilized after the period of peak nesting.

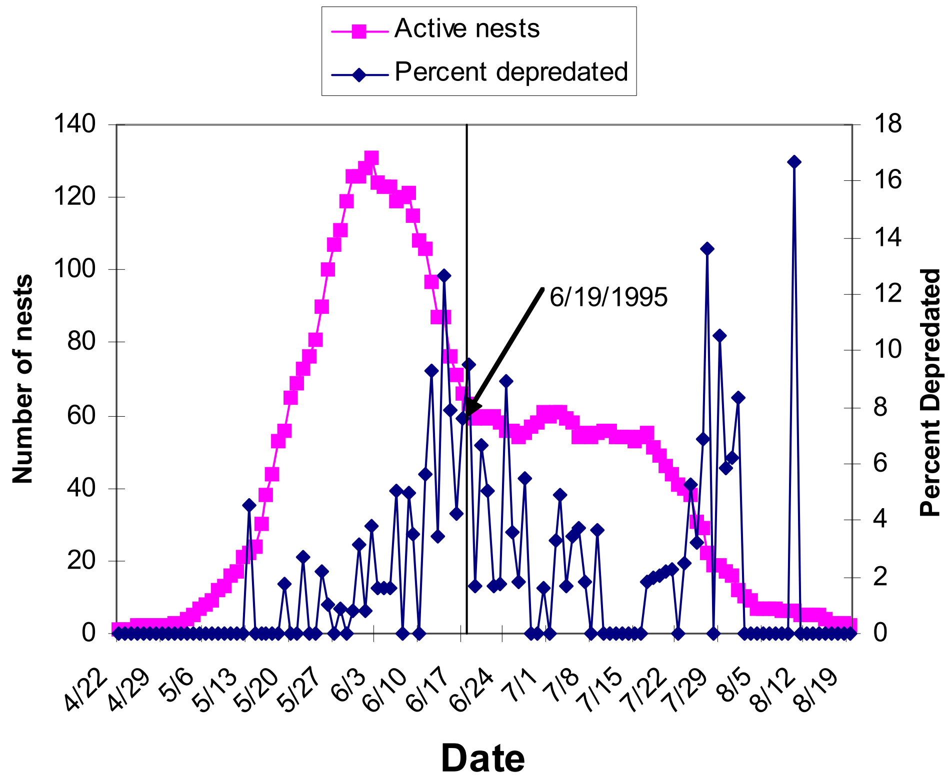
FIG. 3. Number of nests known to be active and monitorable each day in 1995 in eight tracts in Yellowwood, for all species pooled (squares) and for Acadian Flycatchers (diamonds). Also shown are the proportion of Acadian Flycatcher nests depredated each day.

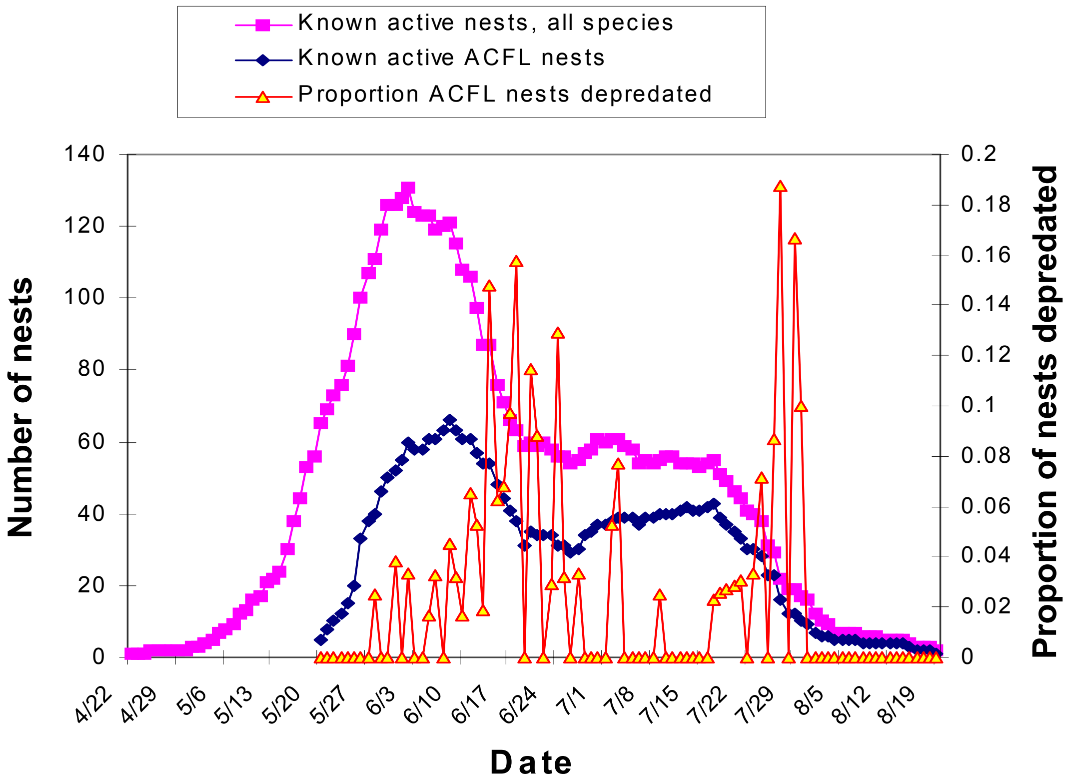
FIG. 4. Daily survival rate of Acadian Flycatcher nests during the (a) egg stage and (b) nestling stage at logged (treatment) and uncut sites in Yellowwood State Forest. Bootstrap standard errors are shown as crossbars.

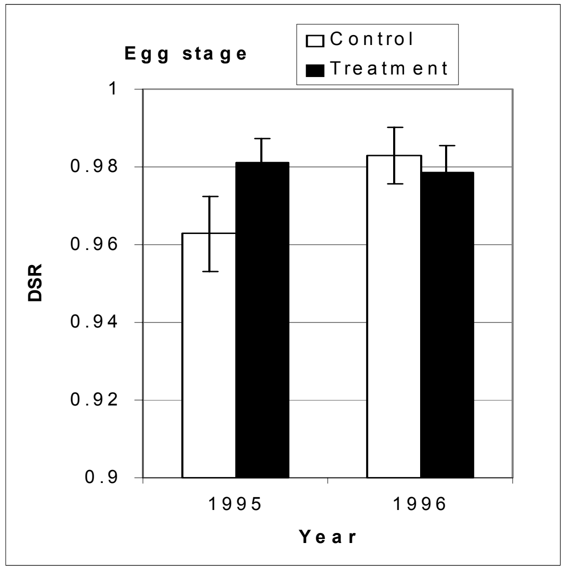
FIG. 5. Overall success rate of Acadian Flycatcher nests in eight tracts in Yellowwood State Forest. Timber was cut in treatment sites between the 1995 and 1996 breeding seasons. Bootstrap standard errors are shown as crossbars.

FIG. 6. Level of cowbird parasitism of Acadian Flycatcher nests in eight tracts in Yellowwood State Forest. Timber was cut in treatment sites between the 1995 and 1996 breeding seasons. Crossbars indicate standard errors estimated from observed frequencies.


N
W
E
S
Nest monitoring plots
Control tracts
Logged tracts
Streams and shorelines
Roads
Yellowwood State Forest
5
0
5
10 Kilometers

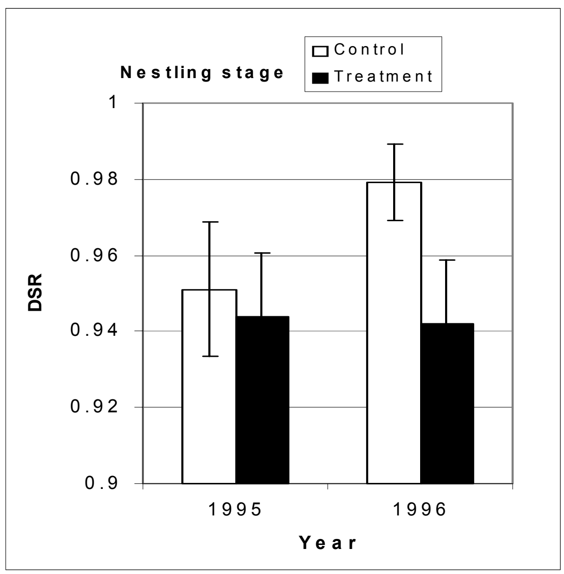

Active nests
Percent depredated
Number of nests
Percent Depredated
6/19/1995
Date
140
120
100
80
60
40
20
0
18
16
14
12
10
8
6
4
2
0
4/22
4/29
5/6
5/13
5/20
5/27
6/3
6/10
6/17
6/24
7/1
7/8
7/15
7/22
7/29
8/5
8/12
8/19


Known active nests, all species
Known active ACFL nests
Proportion ACFL nests depredated
Number of nests
Proportion of nests depredated
Date
0
20
40
60
80
100
120
140
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
4/22
4/29
5/6
5/13
5/20
5/27
6/3
6/10
6/17
6/24
7/1
7/8
7/15
7/22
7/29
8/5
8/12
8/19



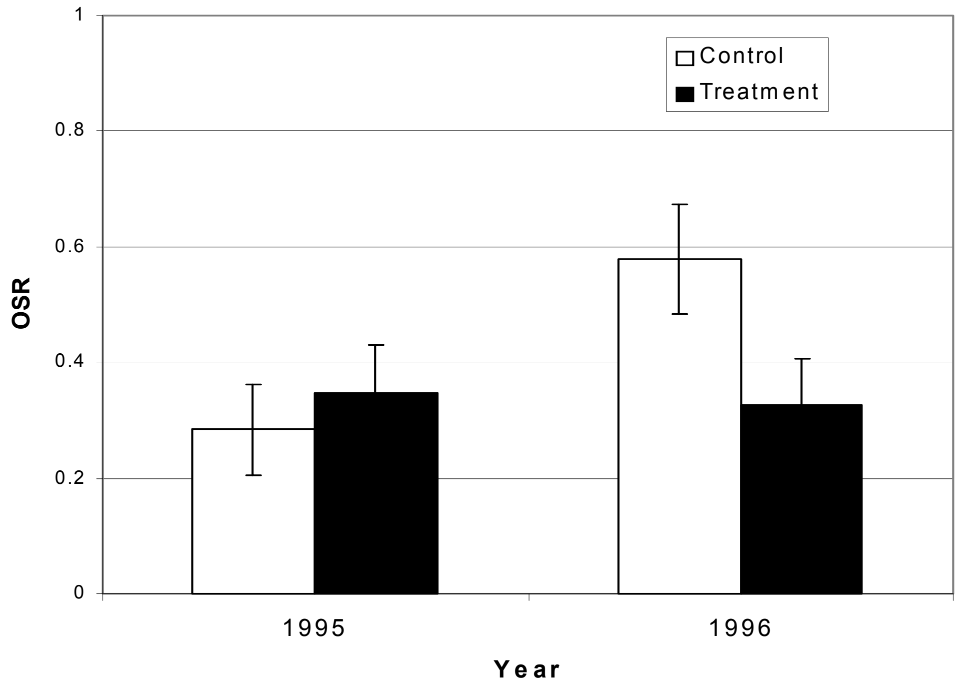
Egg stage
Control
Treatment
DSR
1
0.98
0.96
0.94
0.92
0.9
1995
1996
Year


(A)

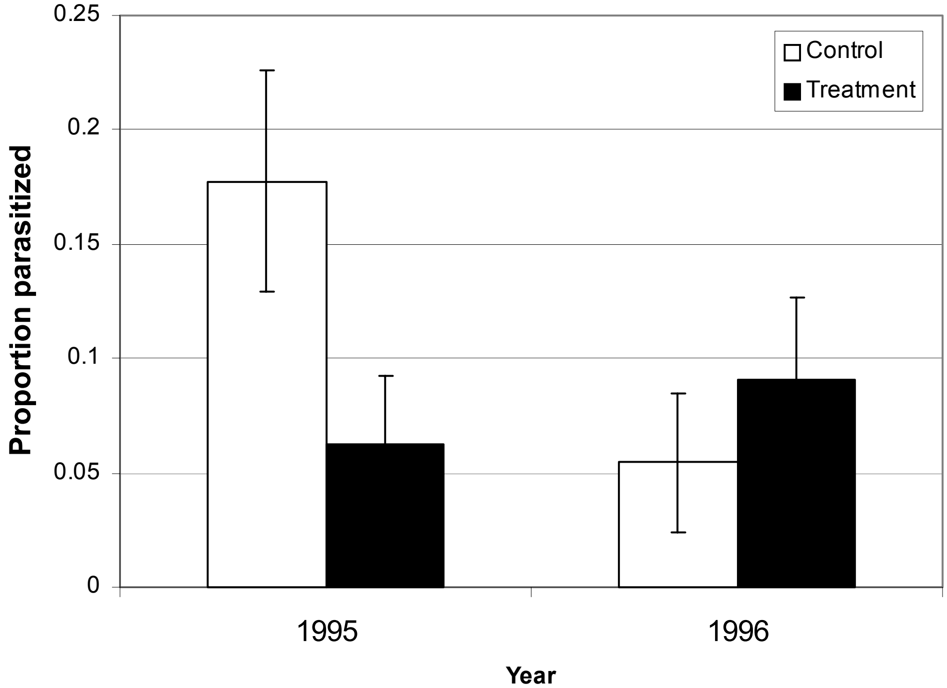


Nestling stage
Control
Treatment
DSR
1
0.98
0.96
0.94
0.92
0.9
1995
1996
Year


(B)



1
0.8
0.6
0.4
0.2
0
OSR
Control
Treatment
1995
1996
Year


0.25
0.2
0.15
0.1
0.05
0
Proportion parasitized
Control
Treatment
1995
1996
Year