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ABSTRACT

As the number of people participating in non-consumptive recreational activities continues to grow, it is becoming increasingly important to quantify the effects of recreational disturbance on wildlife populations. Disturbances from recreational trail-use may alter the behavior and reduce the reproductive success of passerine birds, possibly causing areas developed with recreational trails to function as sink habitats. Riparian systems are important breeding sites for many species of passerine birds, but are also selected as locations for recreational trails. Quantifying the impacts of recreational trail-use on wildlife populations is necessary for managers faced with making decisions regarding conflicting land-uses. This research examined the effects of recreational trail-use on the behavior and nesting success of American robins (*Turdus migratorius*) and yellow warblers (*Dendroica petechia*) in willow/cottonwood riparian habitats in Boulder County, Colorado. Results indicate that increasing intensity of recreational trail-use is associated with reduction in variation of incubation and feeding behavior for both American robins and yellow warblers. For both species the proportion of incubation time increased and food delivery rate decreased with increasing recreational trail-use. The proportion of time incubating was significantly correlated with an overall measure of recreational disturbance for yellow warblers. Additionally for yellow warblers, the overall measure of recreational disturbance was a significant predictor of nesting success, with warblers achieving higher nesting success with increasing trail-use. The proportion of nests surviving to distinct stages of the nesting cycle differed between sites with and without recreational trails for both American robins and yellow warblers. Changes in predation pressure due to trails and trail-use may be a factor driving some of the differences in nesting success. Differences in the strength of behavioral response and in nesting success in relation to recreational trail-use indicate that American robins and yellow warblers are affected differently by trail-use. Understanding the mechanisms through which recreational trail-use affects wildlife populations is necessary in order to determine how best to minimize these forms of disturbance. Learning more about how wildlife populations respond to disturbances from recreational trail-use will benefit future conservation, management, and restoration efforts in woodland riparian habitats.

OBJECTIVES

- To provide management recommendations for minimizing the effects of recreational trail-use on passerine birds.
- To investigate factors affecting the nesting success of American robins (*Turdus migratorius*) and yellow warblers (*Dendroica petechia*) in riparian habitats subjected to varying levels of recreational disturbance.
- To study the effects of disturbance from recreational trail-use on the nesting behavior and reproductive success of American robins and yellow warblers.
- To determine the relationship between nest-site behaviors and nesting success for American robins and yellow warblers.
- To compare the responses of American robins and yellow warblers to recreational disturbance.

HYPOTHESES

Hypothesis 1: Within each species, the behaviors of focal pairs will not be correlated with the intensity of recreational trail-use at each nest-site.

affect passerine birds (van der Zande et al. 1984, Knight and Gutzwiller 1995). Direct effects of recreation involve the alteration of behavior in response to trail-users. Direct disturbance can cause displacement, prevent access to resources, and reduce the reproduction and survival of passerine birds (Gutzwiller et al. 1998). Indirect effects of recreation include factors associated with habitat fragmentation. Fragmentation increases the amount of habitat exposed to edge. Many studies have demonstrated increased rates of nest predation and parasitism by brown-headed cowbirds (*Molothrus ater*) along habitat edges (Yahner 1988, Paton 1994, Robinson and Wilcove 1994). In addition, corridors, such as recreational trails, may provide nest predators and cowbirds access to the interiors of habitats, potentially increasing rates of nest predation and parasitism adjacent to these corridors (Chasko and Gates 1982, Askins 1994, Rich et al. 1994). Furthermore, picnic tables, garbage cans, and human litter associated with recreation may attract potential nest predators and increase rates of nest predation in areas developed with recreational trails (Miller 1994). However other research has shown that some predators may avoid areas that are highly disturbed by humans allowing increased nesting success for birds that can tolerate the human disturbance (Osborne and Osborne 1980, Gering and Blair 1999, Miller and Hobbs 2000).

Studies conducted in Boulder County, Colorado have addressed components of these issues with mixed results. Miller et al. (1998) demonstrated that a pooled sample of passerine birds in ponderosa pine and grassland habitats experience increased nest predation with proximity to trails. Furthermore, in a study conducted within riparian habitats, American robins experienced 100% nest failure along a site with a trail compared to 46% nest failure along a site without a trail (Snyder 1995). However, another study done in riparian habitats showed that predation rates on artificial nests were lower near recreational trails compared to control areas, possibly because of shifts in the predator community due to human disturbance (Miller 1999, Miller and Hobbs 2000). More research on this topic is necessary because of equivocal results and limitations of previous research due to small samples and numbers of replicates, pooling data across passerine species, and basing conclusions on artificial nests (Major and Kendal 1996, Ortega et al. 1998, Miller 1999). In addition, none of these studies has examined the role of different levels of trail-use or the behavioral responses of birds to disturbance from trail-use.

METHODS

Study sites

Study sites included willow/cottonwood riparian woodlands in Boulder County, Colorado where both American robins and yellow warblers occur. Sites were subject to a range of trail-use intensities, including sites without trails on each of the drainages being sampled. All study sites fell within the classification of lowland riparian forest (Andrews and Righter 1992) or lowland riparian ecosystem used by Preston and Kingery (1998). Sites consisted of riparian woodlands, which are surrounded by grassland/agricultural fields. Sections of a few of the sites are bordered by houses or buildings. Vegetation at the sites was not uniform in distribution, and is best described as heterogeneous or patchy. Tree composition was dominated by plains cottonwood (*Populus deltoides*), narrowleaf cottonwood (*Populus angustifolia*), a hybrid of the plains and narrowleaf cottonwood (*Populus* x *acuminata*), and crack willow (*Salix fragilis*). Other relatively common trees include Russian olive (*Elaeagnus angustifolia*), alder (*Alnus tenuifolia*), river birch (*Betula fontinalis*), and hawthorn (*Crataegus* spp.). Interspersed with the trees were thickets of

call, and nest defense behaviors) and what type of disturbance caused this response were recorded, (7) *Chasing Hetero- or Con-specific Intruders*: response to other animals near the nest and identification of the intruding species were recorded.

Quantifying recreational disturbance

During behavioral observations, observers recorded the frequency of each type of recreational trail-user on pre-formatted data sheets. Recreational trail-users were classified as hikers, joggers, bikers, strollers, roller bladers, equestrians, and people with dogs on leash and dogs off leash. Observers also recorded whether users are on or off designated trails. Simultaneously recording bird behavior and recreational trail-use provided data that directly linked trail-use and the associated behavioral responses of focal pairs of birds.

Vegetation sampling

Characteristics of each nest tree and the structure and composition of the surrounding vegetation were measured according to the protocol of Martin et al. (1997). Under this protocol ground and shrub cover within five meters of the nest-site is recorded as well as all the species and size of all trees within 11.3 meters of the nest-site. I also measured the height of each nest (Ortega et al. 1997), distance from the nest to the nearest point on a trail (Miller et al. 1998), the width of riparian vegetation where the nest is located (Miller 1999), and estimate nest concealment (McLean et al. 1986, Johnson 1997). These additional data were collected because these are all factors that may have affected the behavioral responses and nesting success of pairs of birds associated with nests.

Data analysis

To avoid problems with pseudoreplication, data from different behavioral observations taken at the same nest were averaged (Martin and Bateson 1993). Each nest was treated as a replicate. Behavioral data were analyzed separately between the egg and nestling stages of the nesting cycle. For data from the nestling period that showed highly significant correlations with nestling age, regression analysis was used to remove the effects of nestling age before perfoming further analysis on the behavioral measures (Woodard and Murphy 1999). Because observation length varied in duration, all data for behavioral measures and recreational use were converted to proportions of total time or rates. Principal components analyses were used to examine whether the numerous recreational use variables can be reduced to a subset of meaningful factors for use in subsequent statistical analyses. Correlation analyses were used to test whether measures of behavior vary with intensity of recreational trail-use. Logistic regression analyses were used to test which behavioral, disturbance, and nest-site characteristic variables best predict nesting success. Chi-square tests were utilized to examine differences in nesting success between the egg and nestling stages of the nesting cycle and between American robins and yellow warblers.

RESULTS AND DISCUSSION

American robins

For American robins, the factor analyses of the recreational use data from both the egg and nestling stages of the nesting cycle produced two meaningful factors. The first factor produced high loadings on all the disturbance measures (hikers, joggers, bikers, strollers, roller bladers, with dogs on leash and dogs off leash loading slightly lower) and will be

Additional research in these riparian habitats has demonstrated decreases in the abundance of small mammals near trails (Meaney 1999), and lower than expected depredations of artificial nests preyed on by mammals, especially small mammals, near trails (Miller 1999). It may be that avian nest predators are depredating most of the nests at both the egg and nestling stages of the nesting cycle at sites with trails. Whereas at sites without trails, small mammals may be the major predators preying upon nests at the egg stage, but once eggs hatch the nestlings may be too large or capable of defending themselves against small mammals at the sites without trails.

Yellow warblers

For yellow warblers, the factor analyses of the recreational use data from both the egg and nestling stages of the nesting cycle produced two meaningful factors. The first factor produced high loadings on all the disturbance measures (hikers, dogs on leash, dogs off leash, and joggers, with bikers and strollers loading slightly lower) and will be referred to as the *overall disturbance factor*. The second factor loaded high for both strollers and bikers and loaded strongly negative for dogs off leash and will be referred to as the *biker factor*. The two factors explained over 77% of the total variation in the use variables for the model from the egg stage of the nesting cycle and over 82% of the total variation in the use variables for the model from the nestling stage (Table 1). The disturbance factors were all adjusted so that sites with no total users had disturbance factors equal to zero. For data taken only from nests with eggs, based upon examination of the correlation matrix for behavioral measures, only the proportion of time spent incubating, proportion of time the male was vigilant, total (combined male and female) nest defense rate, and total (combined male and female) response rate to trail-users were utilized as independent variables due to high correlations with other variables. The proportion of time that the female incubated was significantly positively correlated with the overall disturbance factor ($r=0.42$, $p<.035$; Figure 4). Other behavioral measures did not demonstrate significant correlations with either of the disturbance factors.. Based on logistic regression analysis, the overall disturbance factor was a significant predictor of nesting success ($p<0.02$), with nests at more disturbed sites more likely to succeed (Figure 4).

The following results were obtained from analysis of the data from only the nestling stage of the nesting cycle. Based on examination of the correlation matrix, proportion of time spent incubating, proportion of time that the female was vigilant, proportion of time the male was vigilant, total (combined male and female) food delivery rate, total (combined male and female) nest defense rate, and total (combined male and female) response rate to trail-users were utilized as independent behavioral variables. None of the behavioral measures demonstrated significant correlations with either of the disturbance factors. Though, visual inspection of scatter plots indicates that disturbance may influence the variance in behavioral measures (e.g. increasing total user rate reduces the variance in total food delivery rate, Figure 5). None of the behavioral measures or disturbance measures were significant predictors of nesting success based on logistic regression analysis, although this could be due to only two of 17 nests observed with nestlings failing (Figure 5).

For yellow warblers, eleven of 27 (40.7%) of nests at sites with trails were successful, but only one of 13 (7.7%) of nests at sites without trails was successful, although a chi-square test revealed an insignificant result probably due to small number of nests in some of the cells (Table 3).

Finally, the nesting success of American robins and yellow warblers was shown to differ significantly, indicating that species of open-cup nesting passerine birds can be differentially affected by recreational trails and use. This finding, as well as the finding that yellow warblers may have a more significant behavioral response to trail-use than American robins, indicate that it is important to look at individual species responses to trail-use, as opposed to pooling data across species as was done by Miller et al. (1998).

PRELIMINARY RECOMMENDATIONS

I have documented evidence for a behavioral shift for both American robins and yellow warblers with increasing trail-use. It seems that both of these species exhibit a full range in the variation of some of their behaviors at sites without, or with minimal, recreational disturbance levels. Thus, to allow for the complete natural range of behavioral variation for these species some portions of riparian habitats should remain free of recreational trails and other areas with low levels of trail-use should have management objectives that seek to maintain low user levels.

Other results conflict with some of the findings of previously conducted studies and will need additional data to clarify. There may be fitness costs associated with nesting at more disturbed sites which I have not detected yet. In addition, recent investigations have documented population declines and in some cases local extirpation of yellow warbler populations from areas of high human disturbance, such as some areas along Boulder Creek (Kuenning 1998; Miller 1999; Alexander Cruz, personal communication). It will be important to continue to monitor yellow warblers populations at sites with trails, especially along South Boulder Creek, to insure that those populations continue to persist as levels of recreational use continue to increase.

FUTURE PLANS

I will continue to analyze data collected in the last two field seasons, including data on nest-site characteristics for both species.

Upon approval of my research proposal, I will continue to collect similar data next summer to further build upon and validate my results. I will be especially interested in trying to find more nests at high-use sites and finding more yellow warbler nests. I would also like to examine whether the behavioral differences noted above have fitness costs.

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TABLES

Table 1- The percentage of variation accounted for by the two factor principal component analyses by model (* note that roller-bladers were not included in the yellow warbler models because of low numbers of observations)

Model	Hikers	Joggers	Bikers	Dog On	Dog Off	Strollers	Roller-bladers
AMRO Eggs	88.1	91.0	93.6	75.9	90.3	82.8	96.2
AMRO Nestlings	79.1	54.4	88.4	60.6	88.9	72.9	91.8
YWAR Eggs	90.3	61.1	77.2	77.2	88.4	84.4	*
YWAR Nestlings	92.0	74.0	94.9	90.0	91.3	54.0	*

Table 2- The frequency of nests failing at each stage of the nesting cycle compared to fledging for American robins pooled for sites with and without recreational trails.

	No Eggs	Eggs	Nestlings	Fledge	Total Nests	Total Successful	Total Fail
Trail	3	19	11	34	67	34	33
No Trail	2	11	1	20	34	20	14

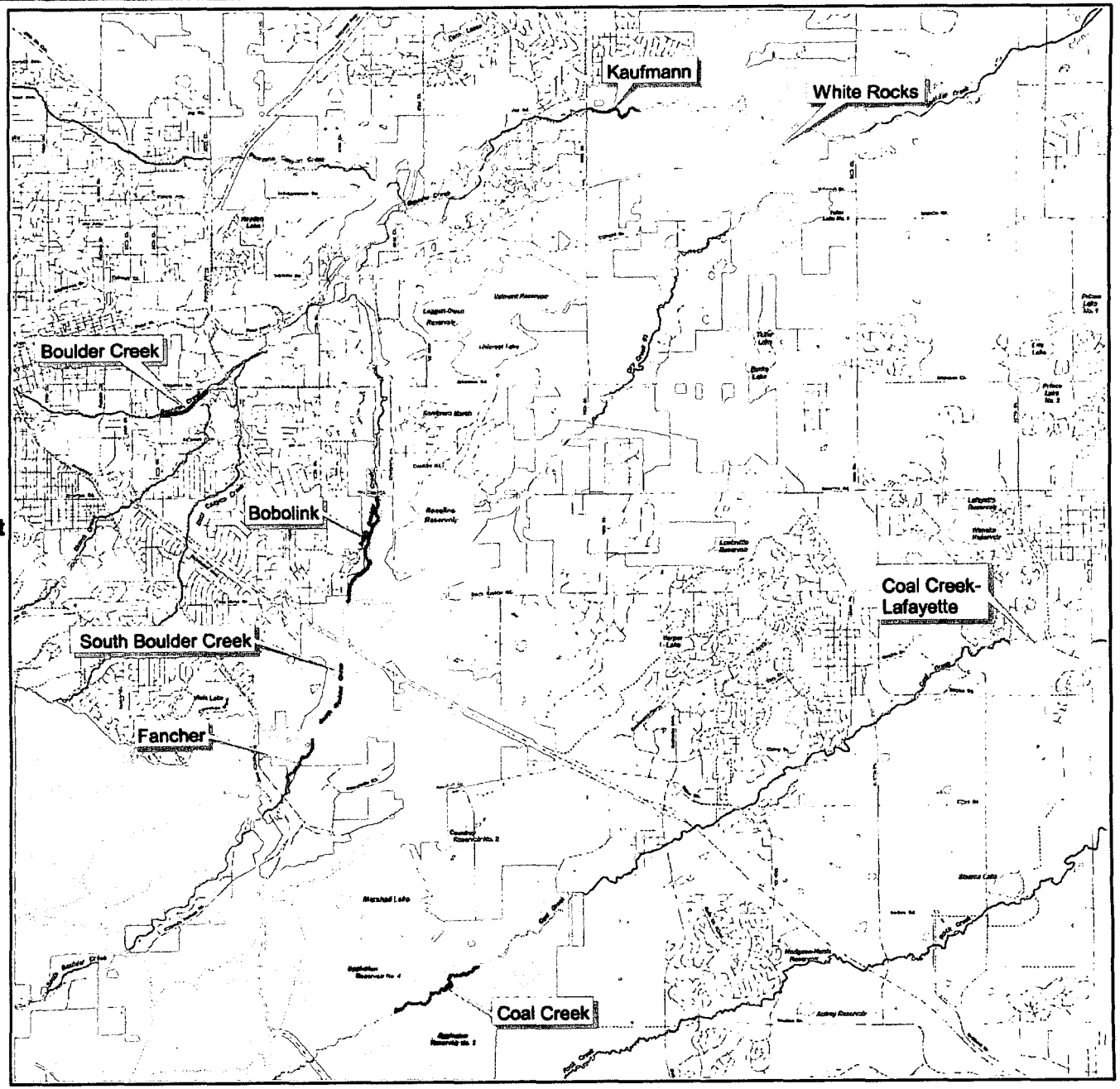
Table 3- The frequency of nests failing at each stage of the nesting cycle compared to fledging for yellow warblers pooled for sites with and without recreational trails.

	No Eggs	Eggs	Nestlings	Fledge	Total Nests	Total Successful	Total Fail
Trail	3	10	3	11	27	11	16
No Trail	4	7	1	1	13	1	12

STUDY SITES

Study Sites
- High Use
- Low Use
- No Trail
- CREEK
- Lakes and Reservoirs
- Trails
- Roads

City of Boulder Open Space
- Open Space
- Conservation Easement



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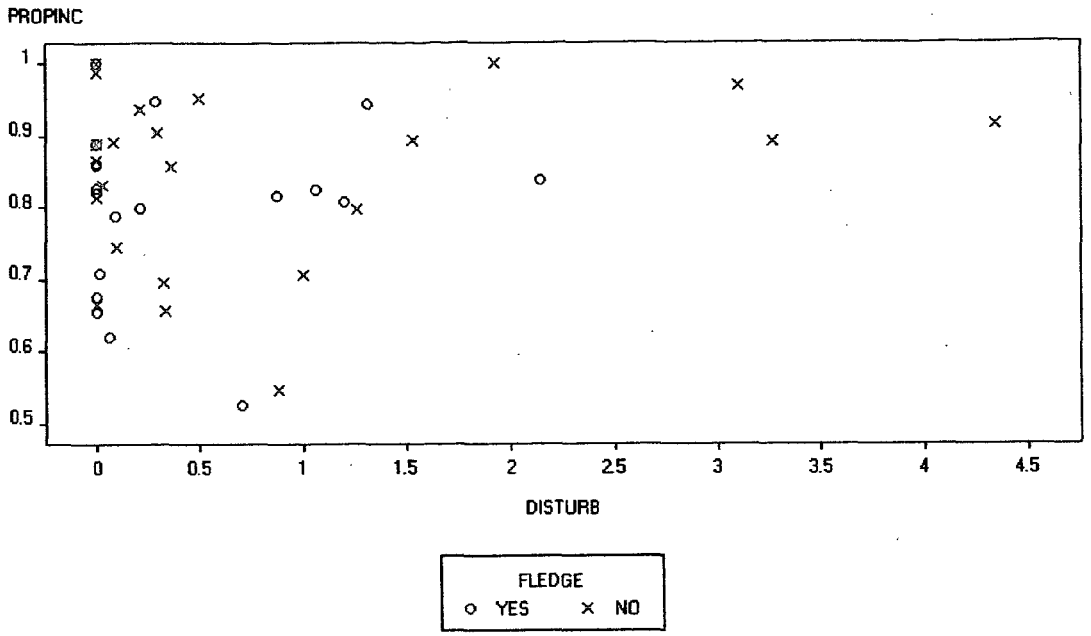

Figure 2- Proportion of time spent incubating (PROPINC) versus the overall disturbance factor (DISTURB) for American robins from data in the egg stage of the nesting cycle. Open circles indicate nests that subsequently fledged while X's show failed nests. n=43 observed nests.

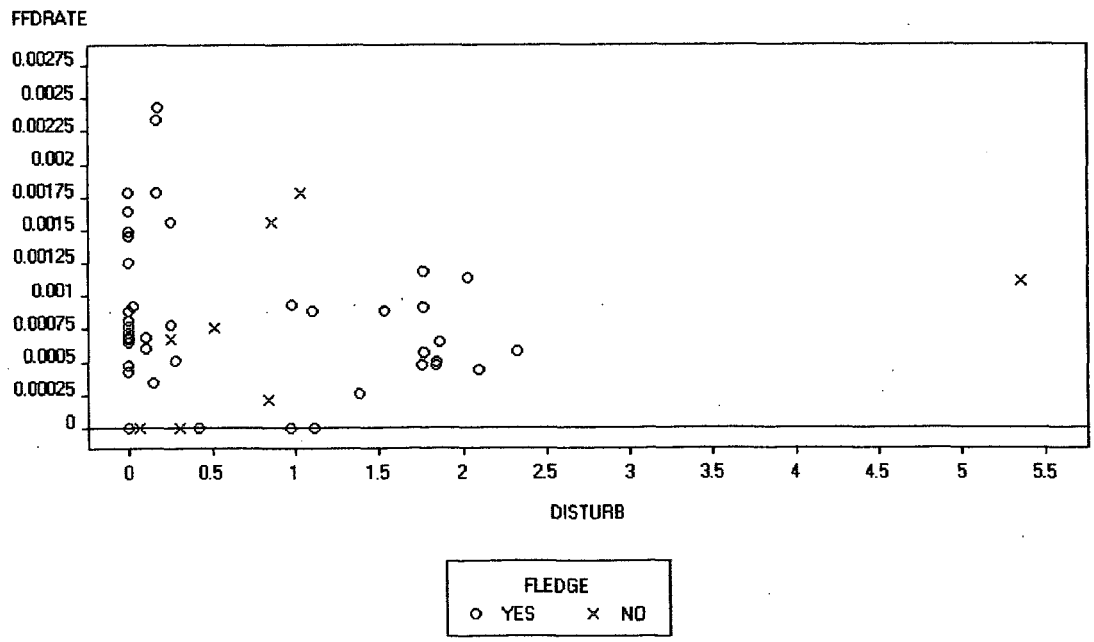

Figure 3-Female food delivery rate (FFDRATE) versus the overall disturbance factor for American robins from data in the nestling stage of the nesting cycle. Open circles indicate nests that subsequently fledged while X's show failed nests. n=51 observed nests.