7-13-2003

# Guidelines for Finding Nests of Passerine Birds in Tallgrass Prairie

Maiken Winter
*State University of New York*

Shawn E. Hawks
*University of Minnesota - Crookston*

Jill A. Shaffer
*USGS Northern Prairie Wildlife Research Center*, jshaffer@usgs.gov

Douglas H. Johnson
*USGS Northern Prairie Wildlife Research Center*, Douglas_H_Johnson@usgs.gov

Published in The Prairie Naturalist 35(3): September 2003.
Published by the Great Plains Natural Science Society
http://www.fhsu.edu/biology/pn/prairienat.htm

# Guidelines for Finding Nests of Passerine Birds in Tallgrass Prairie

**MAIKEN WINTER[1], SHAWN E. HAWKS[2], JILL A. SHAFFER, and DOUGLAS H. JOHNSON**

State University of New York, College of Environmental Sciences and Forestry, 1 Forestry Drive, Syracuse, NY 13210 (MW)
University of Minnesota, Crookston, MN 58105 (SEH)
U.S. Geological Survey, Northern Prairie Wildlife Research Center, 8711 37th St. SE, Jamestown, ND 58401 (JAS, DHJ)

**ABSTRACT** -- The productivity of birds is one of the most critical components of their natural history affected by habitat quality. Birds might occur at high densities in a given habitat patch but have low nesting success. Such "population sinks" would not be detected if observers relied solely on estimates of bird density. Therefore, it is essential to monitor nests and determine their outcomes. Although interest in grassland-nesting passerines has increased greatly during the last decade, we still know little about factors affecting their nesting success. To stimulate more research in this area, we summarize several methods for nest-searching and provide suggestions for optimizing its success in tallgrass prairie. As a case study, we provide some data from a study on grassland-nesting birds in the northern tallgrass prairie.

**Key words:** bobolink, clay-colored sparrow, grassland birds, methods, nest-searching, Savannah sparrow, tallgrass prairie.

The nesting biology of some grassland-nesting passerines is still an enigma, especially for secretive species such as Le Conte's sparrow (*Ammodramus leconteii*) (Dechant et al. 1998). To develop conservation strategies for this group of birds, many of which have been suffering population declines (Peterjohn and

---

[1]Mailing Address: Laboratory of Ornithology, Cornell University, 159 Sapsucker Woods Rd., Ithaca, NY 14850.
[2]Current address: North Dakota State University, Fargo, ND 58105-5517.

Sauer 1999), we need to better understand how different factors (e.g., rates of nest depredation by predators and nest parasitism by brown-headed cowbird [*Molothrus ater*]) affect nesting success of grassland passerines. In addition, nesting success can vary greatly among years, regions, and even local study plots (Winter et al. 1998, 1999, 2000, 2001). This variability indicates the need for more studies across a wider geographical range to investigate the factors that influence nesting success. However, some researchers shy away from searching for grassland bird nests, mainly because nests of many of these species are inconspicuous and therefore hard to find (Bent 1968). Instead, most studies of grassland-nesting birds are restricted to presence/absence or density information, even though census data do not always reliably reflect the quality of a habitat for a given species (Van Horne 1983, Winter and Faaborg 1999). A reproductive index that bases estimates of nesting success on behavioral observations (Vickery et al. 1992) has recently been shown to be inappropriate for some species (Rivers et al. 2003).

We describe four general methods of searching for nests of passerines in tallgrass prairie, and suggest ways to improve their success. We use nesting data from our study in Minnesota and North Dakota tallgrass prairie as an example (Winter et al. 1998, 1999, 2000, 2001). For a detailed description of the general behavior of birds during different stages of the nesting cycle, see Martin and Geupel (1993), and for detailed descriptions on setting up a nest-searching study, nest-monitoring, and determining nest fate, see Martin et al. (1997). Ultimately, we hope to stimulate more research on the nesting biology of grassland passerines in order to improve our ability to manage grassland habitats for these birds.

## METHODS OF NEST-SEARCHING

Nest-searching can be both extremely rewarding and extremely frustrating. It requires strong observational skills, patience, and knowledge of the breeding biology of the species of concern. For a person with these characteristics, minimal training is required to become successful at finding nests. The success of any nest-searching method depends upon an observer's knowledge of where birds nest, how nesting birds behave, the best time of day and time during the breeding season to search for nests, and how to mark nests so as not to lose them within a homogeneous environment.

Nests of grassland birds typically are located on the ground (e.g., bobolink [*Dolichonyx oryzivorus*], Bent 1965) or within live or dead plant material several cm above the ground (e.g., Le Conte's sparrow, Bent 1968). A few species generally place their nests higher above the ground in tall forbs or low shrubs (e.g., dickcissel [*Spiza americana*], Winter 1999; clay-colored sparrow [*Spizella pallida*], Bent 1965, 1968). Knowledge of general habitat preferences, such as topography, soil moisture, and vegetation structure (for an overview see Johnson and Igl 2001), enable the observer to focus nest-searching for an individual species on a particular area. However, within the general habitat preferred by a species, a bird potentially can place its nest anywhere. Therefore, specific search images for nest sites (e.g., grass clumps, large accumulations of dead plant material) should only be used after a search area is narrowed down to about 1 $m^2$. This is in contrast to many forest-breeding species, for which the observer can focus nest-searching on more specific habitat features (e.g., trees, shrubs, roots). Nest-searching methods for grassland birds can therefore differ greatly from those for forest species (Martin and Geupel 1993).

Besides the general habitat preferences of grassland birds, their behavior also must be considered. A critical aspect of the behavior of many grassland-nesting passerines, especially grassland sparrows, is their tendency to walk, rather than fly, to and from their nest. Consequently, the site where a bird enters or departs from the vegetation can be up to 5 m from the nest itself. During the nestling stage, adult birds are more likely to fly directly to the nest. However, a feeding adult might fool the observer by disappearing into the vegetation with food, only to come up again a few minutes later with food still in the bill. Therefore, an observer should wait until the bird reappears without food, and observe feeding at least three times before attempting to find a nest. Breeding birds are most likely to flush directly from their nest early in the morning and early in the breeding season. Therefore, nest-searching is most productive during those times (see case study).

Another aspect of behavior is that grassland passerines easily will abandon their nests if disturbed early in the nesting cycle. In order to reduce nest abandonment, the observer should avoid looking for the exact nest location during nest building. Instead, the observer should mark the general vicinity of the potential nest site, and return several days later to locate the nest. Finally, the observer must ensure that the found nest can be relocated. This can be difficult in grasslands because of the uniformity of vegetation and the scarcity of landmarks. Therefore, setting up a grid system with numbered surveyor flags or wooden lathes every 50 or 100 m (depending on the height of the vegetation) can be very useful.

There are four main methods for nest-searching in grasslands: 1) chain or rope dragging, 2) systematic walking with or without a sweeping stick, 3) haphazard walking, and 4) behavioral observation. The applicability of each method varies greatly, depending on the stage of the nesting cycle, the behavior of the individual bird, the time of day, and the structure of the vegetation. Therefore, the following descriptions should be understood as general guidelines that might not always work for the species or individual bird under study. Depending on the circumstances and the species of interest, nest-searching is most effective if one is flexible enough to switch from one method to another.

**Chain or rope dragging**

A long chain (Higgins et al. 1969, Lokemoen and Beiser 1997) or rope (e.g., Koford 1999) is pulled between either two vehicles or two people. Devices hanging from the rope, such as cans and bells, increase the disturbance caused by the rope and thus the likelihood of flushing a bird from its nest (Steve K. Davis, Saskatchewan Wetland Conservation Corporation, Regina, Saskatchewan, personal communication). This method is widely and successfully used in shortgrass and mixed-grass prairie, especially for finding waterfowl nests (Klett et al. 1986). Rope dragging also has been used successfully in pastures where vegetation had been reduced by grazing (Roz B. Renfrew, Vermont Institute of Natural Science, Elmer J. Finck, Fort Hays University, Hays, Kansas; personal communications). Its greatest advantage over any other nest-searching method is that one can cover a large area within a short time. However, in tallgrass prairie we found that rope dragging was less successful than other methods, because the vegetation was often too tall for the rope to cause sufficient disturbance for flushing passerines from their nest (Maiken Winter, personal observation; but see Koford 1999). Similarly, rope dragging was not efficient in dense Conservation Reserve Program fields in Kansas (Elmer J. Finck, personal communication).

**Systematic walking**

Several observers walk systematically across the study plot with or without a "sweeping stick." A sweeping stick is a plastic or an aluminum pole about 1.5 m long that is swept back and forth across the top of the vegetation to flush birds from their nest. Nest-searchers systematically walk parallel to each other and about 4 m apart (such that the tips of the sticks almost touch each other) or closer (when not using a stick) in order to cover the entire study plot during nest-searching.

Nest-searchers walk at a fairly quick pace, and observe the area about 4 m ahead to watch for flushing birds. To stay in a straight line, it might help if the person on the outside of the line drops flags about every 20 m (the distance depends on the height of the vegetation and the topography). On the way back, the person walking on the inside of the line picks up the flags. This method enables nest-searchers to search an entire plot without missing or overlapping areas, and keeps effort consistent from one plot to the next (Steve K. Davis, personal communication). Systematic walking seems to work best during the incubation stage or at cold or hot temperatures, when birds stay on the nest to warm or shade their eggs or young, respectively.

**Haphazard walking**

While walking across the study plot without a predetermined route (alone or in pairs, and with or without a sweeping stick), an observer can nest-search either by flushing a bird from its nest or by detecting birds that indicate close proximity to a nest. The advantage of this method over systematic walking is that more attention can be given to the behavior of the birds, thus facilitating nest finding by behavioral observation (see below). A disadvantage is that it is not possible to closely track the area that has been searched. Therefore, some areas might be missed while others are searched more than once. Haphazard walking works well during any stage of the nesting cycle, but its efficiency varies with the species under study.

A specific type of nest-searching by haphazard walking is the "incidental flush"; nests are found during activities other than nest-searching, such as vegetation measurements or bird censuses. The only difference between incidental flush and haphazard walking is the intention and thus the attentiveness of the observer.

For the above methods to be successful, the observer must recognize which types of flush indicate a nest site. Before flushing, a bird might be engaged in one of several different activities, such as feeding, preening, resting, or incubation. To determine if a bird flushed from its nest, the observer needs to consider 1) the distance between the place from which a bird flushed and the observer, 2) the distance the flushed bird flew away from the observer, and 3) the behavior of the bird after it flushed. What we call a "good flush" occurs when a bird flushes within 1 m of the observer or when a bird drops back down after flying only a few meters. This type of flush often leads to a nest except for extremely furtive species, such as Le Conte's Sparrow or Henslow's sparrow (*Ammodramus henslowii*), and extreme care is necessary to avoid trampling the nest. If a bird flushes 1 to 5 m in front of the observer and flies 5 to 10 m away, the bird probably had detected the approach of the observer and had run away from the nest. Such an "okay flush" might or might not indicate a nest site. One can be relatively confident that a bird did not flush from a nest if it flushed more than 5 m in front of the observer and then flew a fairly long distance (e.g., more than 15 m). However, if the bird is chipping vigorously, it might still be worthwhile to follow up on such a "questionable flush". In some species, such as bobolink (Maiken Winter, personal observation), Le Conte's sparrow, red-winged blackbird (*Agelaius phoeniceus*), and dickcissel (Larry D. Igl, United States Geological Survey, Jamestown, North Dakota, personal communication), the female can be warned by the male, which causes the female to flush up to 10 m from the nest. For these species, we recommend delaying nest-searching until the male has left the area.

Nest-searching always should start at the location where the bird had flushed, which should get marked with flagging tape immediately after the flush. Assuming that the bird walked in a straight line away from its nest before it flushed, the nest-searcher should continue searching by retracing his/her foot-steps up to about 2 m. If a nest cannot be found within 10 min, the observer should leave the area and return about 30 min later and try to flush the bird again ("directed flush"), preferably approaching the nest site from a different direction. The directed flush technique might increase the chance of nest abandonment, but our data provide no evidence of such an effect (see Table 1).

**Behavioral observation**

Any of the above methods can lead to an observation of a potentially nesting bird. Of all the methods, behavioral observation requires the most patience and the highest attentiveness. It should be used only when the observer is certain that a bird indicated a nest site. Therefore, the observer should learn the behavior of the species well enough to know which cues indicate a nearby nest site. Potential cues are: 1) alarm chipping, 2) flushing within 5 m and flying only a short distance, 3) nest material in the bill, 4) food in the bill, 5) fecal sac in the bill, 6) members of a pair in close vicinity to one another, 7) distraction displays, 8) repeated flights towards a distinct area, and 9) begging vocalizations by nestlings.

Unlike forest situations, observing bird behavior in grasslands has the advantage that there are no trees obstructing the view of the observer. However, this advantage is offset by several disadvantages:

1. Members of the breeding pair can see the observer just as well as the observer can see the pair. To minimize disturbance, the observer needs to be as inconspicuous as possible by either sitting in tall vegetation or standing behind a shrub or hill. Fondell et al. (2000) suggested using a mobile tower blind for observation, which they successfully used in a western Montana grassland.

2. Bird density is often so high that the observer might be sitting in a territory of a bird different from the one under observation. The observer should stay focused on one bird, and not get distracted by another chipping bird. Trying to observe more than one bird mostly leads to losing both. However, if the chipping of a neighboring bird persists, the observer should move to another location to minimize disturbance.

3. The scarcity of reference points in homogeneous grasslands makes it difficult to determine the exact location of a potential nest, especially the distance from the researcher to a bird that is being observed. To ameliorate this problem, the observer should attach flagging tape in a triangle around the area of the potential nest site with flags about 1 to 2 m apart. This procedure helps the observer to pinpoint the location in which a bird disappeared. But even with flagging tape, the exact location where a bird dropped down into the vegetation is sometimes difficult to determine. If this is the case, the observer should watch a potential nest site from several different angles.

If no flagging tape has been deployed, the observer should know exactly where to go before entering the area of a potential nest. This is accomplished by identifying reference points between the observer and the nest (e.g., tall forbs, patches of grass) or at the horizon (e.g., trees, shrubs, houses) before standing up.

**Table 1.** Percentage of nests found and percentage of nests abandoned in each of the three stages of the nesting cycle, organized by species and nest-searching method, 1998 to 2001.

| Species[1] | Method | Egglaying | Incubation | Nestling | Unknown[2] | Total |
|---|---|---|---|---|---|---|
| Bobolink (n = 315) | Behavioral observation | 3.9 | 32.9 | 41.6 | 21.6 | 73.6 |
| | Systematic walking | 18.2 | 22.7 | 4.5 | 54.6 | 7.0 |
| | Haphazard walking | 6.2 | 25.0 | 21.9 | 46.9 | 10.2 |
| | Incidental flush | 20.8 | 41.7 | 4.2 | 33.3 | 7.6 |
| | Direct flush | 20.0 | 40.0 | 40.0 | 0.0 | 1.6 |
| | Total % | 6.7 | 32.1 | 34.1 | 27.1 | 100.0 |
| | Abandoned %[3] | 0.0 | 32.1 | 2.0 | 25.0 | 7.9 |
| | | (1) | (53) | (249) | (12) | (315) |
| Clay-colored sparrow (n = 789) | Behavioral observation | 14.1 | 29.6 | 38.7 | 17.6 | 28.8 |
| | Systematic walking | 17.7 | 38.2 | 4.3 | 39.8 | 32.2 |
| | Haphazard walking | 20.4 | 41.5 | 9.9 | 28.2 | 28.0 |
| | Incidental flush | 16.7 | 39.8 | 7.7 | 35.8 | 9.9 |
| | Direct flush | 0.0 | 66.7 | 11.1 | 22.2 | 1.1 |
| | Total % | 17.1 | 37.1 | 16.2 | 29.6 | 100.0 |
| | Abandoned % | 44.4 | 18.3 | 1.6 | 24.1 | 8.6 |
| | | (18) | (213) | (508) | (54) | (793) |
| Savannah sparrow (n = 681) | Behavioral observation | 3.7 | 24.8 | 57.7 | 13.8 | 52.0 |
| | Systematic walking | 9.8 | 33.1 | 10.7 | 46.4 | 16.4 |
| | Haphazard walking | 15.2 | 46.6 | 15.3 | 22.9 | 17.3 |
| | Incidental flush | 16.3 | 42.5 | 16.2 | 25.0 | 11.7 |
| | Direct flush | 29.4 | 29.4 | 29.4 | 11.8 | 2.5 |
| | Total % | 8.8 | 32.2 | 37.0 | 22.0 | 100.0 |
| | Abandoned % | 33.3 | 25.0 | 0.8 | 20.6 | 6.3 |
| | | (12) | (112) | (529) | (34) | (687) |

[1] The number of nests (n) is lower than the total number of nests reported for clay-colored and Savannah sparrows in Table 1 because the search method was not recorded for all nests.

[2] The stage of the nesting cycle was unknown when nests that were found with an incomplete clutch were depredated at the next nest check.
[3] Percent of all nests in that nesting stage that were abandoned, with number in parenthesis equal to n.

The observer should recheck these reference points before walking to the nest site because vegetation can look very different when sitting versus standing.

A fifth method for nest-searching (which we did not use) that is being tested currently is the use of infrared cameras (Mike Guzi, University of Wisconsin, Madison, Wisconsin, personal communication). These cameras are able to detect the heat given off by eggs, young, or an incubating adult. However, it is not yet known how well these cameras work in areas of deep litter and tall vegetation. In addition, cameras are expensive such that only well-funded researchers will be able to use them.

Observer and species biases exist for each of the four nest-searching methods that we described. Because nest-searching is generally species-specific, success in finding nests with any of the methods depends on a species' behavior and habitat preferences. For example, our data indicate that nest-searching by behavioral observation favors some species (e.g., the bobolink; Table 1). Larry D. Igl (personal communication) noticed a similar bias for the dickcissel. Because observers often focus on a few species or individuals, behavioral observation has some degree of subjectivity. This bias can be problematic when the purpose of a study is to determine how many species nest in a given area. If this is the case, then nest-searching by rope dragging or systematic walking is more objective and will give a less observer-biased overview of the nesting species present.

## MARKING THE NEST SITE AND INFLUENCES OF OBSERVERS AT THE NEST

Because many grassland bird nests are extremely difficult to find, observers should use great care to avoid losing a nest that has already been found. We placed a nest flag 5 m north of the nest to identify the nest location. On a nest card, detailed directions and nest observations should be recorded (Martin et al. 1997). This is especially true in grazed areas, where a cow's (*Bos taurus*) curiosity for flagging material might cause markers to be lost and thereby lead to lost nests. To help alleviate this problem, the observer should mark the ground with non-toxic spray-paint 5 m north of the nest instead of, or in addition to, using nest flags. Another method to prevent cattle from eating nest markers is to use thin rebar with the tips painted orange (Diane A. Granfors, United States Fish and Wildlife Service, Fergus Falls, Minnesota, personal communication), or piles of rock (Elmer J. Finck, personal communication). In addition, taking compass bearings from another reference point to the nest site, or taking GPS readings at the nest site might be helpful. For nests that were extremely hard to find, we placed a tiny piece of flagging tape on vegetation about 30 cm south of the nest to help relocate the nest during nest-monitoring (for detailed instructions on nest-monitoring see Martin et al. 1997). This piece of flagging tape should be as inconspicuous as possible so as not to attract predators.

To avoid influencing the natural outcome of nests, the observer should disturb the nest and its vicinity as little as possible during both nest-searching and nest-monitoring. Therefore, the observer should:

1. Avoid trampling the nest and the surrounding vegetation by leaving as few footsteps as possible at the nest site, and by avoiding nest-searching immediately after rain. When morning dew is heavy, the observer should mark the general area where a nest is assumed to be, and come back later in the morning - when the dew has evaporated - to find the nest.

2. Not look for a nest until the potential nest site is narrowed down to an area of about 1 $m^2$. In addition, the observer should wait until the bird has left the nest site, and spend only 10 min or less actively looking for a nest.

3. Avoid re-flushing birds that take over an hour to return to their nests after the previous flush. Instead, the observer should wait until the next scheduled visit to try to find their nest. These birds are more sensitive to disturbance, and are therefore probably more prone to abandon their nests.

4. Leave the nest site as quickly as possible after a nest has been found or checked, and move at least 20 m from the nest before recording information on the nest card.

5. Not walk the same way to and from the nest when revisiting a nest; instead, the observer should walk from a nest flag past the nest. This will minimize the possibility that nest predators follow the observer's footsteps to the nest.

6. Not interfere with the natural outcome of a nest by influencing nest predators or brown-headed cowbirds. The observer should delay nest-searching or nest-checking if predators or brown-headed cowbirds are nearby.

## A CASE STUDY

In our study of grassland-nesting birds in Minnesota and North Dakota, we searched for nests in 30 study sites, ranging between 3 and 16 ha (Winter et al. 2001). The study was conducted during four years (1998-2001) between 15 May and 30 July. Depending on the weather conditions, nest-searching began at dawn (about 0500) and lasted until at least 1200. We focused nest-searching and monitoring efforts on bobolink, Savannah sparrow (*Passerculus sandwichensis*), and clay-colored sparrow, but we also monitored nests of other species that we found incidentally. Because our study was not set up to examine the efficiency of different nest-searching methods, we did not consistently record the time we spent nest-searching.

During four field seasons, we found 2075 grassland passerine nests with the help of an average 12.2 field assistants and 1 to 2 volunteers per year (Table 2). The number of grassland bird nests found per field assistant ranged from 10 to 108. On average, each field assistant found about four grassland bird nests per week. The wide range of nest-searching abilities and the low number of grassland passerine nests found by the average field assistant indicate that many field assistants are needed to ensure a large number of nests. Given the low number of nests found per human effort, researchers with little funding to employ field assistants might want to consider behavioral observations to generate measures of reproductive success (Vickery et al. 1992). However, these estimates might not be representative of reality (Rivers et al. 2003).

The number of nests found is not only influenced by the experience of the observer, but also by the 1) number of active nests on a plot, 2) amount of time spent searching, 3) nest-searching method, 4) light conditions and temperatures at different times of the day, and 5) time in the breeding season. Because we do not know the amount of time spent nest-searching, we can not compare the efficiency of nest-searching methods, nor determine at which times during the day and during the breeding season it is most productive to look for nests. However, based on our experience we suggest that the following observations are generally true for our study system, and might be applicable to other sites.

Most nests of all grassland passerines combined (see Table 2) were found by behavioral observation (n = 859), followed by systematic (n = 459) and haphazard walking (n = 453). More than 10 % of the nests were found incidentally (n = 252) (i.e., during activities other than nest-searching). A few nests were found by directed flush (n = 33). Because we found only two nests with rope-dragging, we did not continue using this method after the first year of the study. The large percentage of nests found incidentally points out that observers need to be highly attentive to bird behavior during the entire stay on a study plot.

During the peak nest-searching hours (0500-1200), most nests were found

**Table 2.** Number of nests found for each of the grassland passerines monitored in Minnesota and North Dakota tallgrass prairie, 1998 to 2001.

| Common name | Scientific name | Number of nests found |
|---|---|---|
| Clay-colored sparrow | *Spizella pallida* | 793 |
| Savannah sparrow | *Passerculus sandwichensis* | 687 |
| Bobolink | *Dolichonyx oryzivorus* | 315 |
| Western meadowlark | *Sturnella neglecta* | 71 |
| Le Conte's sparrow | *Ammodramus leconteii* | 51 |
| Grasshopper sparrow | *Ammodramus savannarum* | 39 |
| Brewer's blackbird | *Euphagus cyanocephalus* | 37 |
| Vesper sparrow | *Pooecetes gramineus* | 28 |
| Sedge wren | *Cistothorus platensis* | 28 |
| Lark sparrow | *Chondestes grammacus* | 25 |
| Henslow's sparrow | *Ammodramus henslowii* | 1 |

between 0600 and 1100. Light conditions before 0600 are often unfavorable for spotting a flushed bird and for finding nests. After 1100, adults spend more time off their nest, such that nest-searching becomes less efficient. In addition, less time was spent nest-searching in the late mornings and early afternoons. We did not attempt to nest-search during early evening hours, because adults might not return to the nest for the night when nests are disturbed later in the day.

Most nests were found between the end of May and the end of June. The low number of nests found early in the season might partly reflect the inexperience of the observers. Therefore, the field season should start early enough such that proper experience has been acquired before the peak of the nesting season. Nesting grassland birds are also least conspicuous during nest-building and egg-laying (Maiken Winter, personal observation). Few nests were found in July, probably because less time was spent nest-searching due to extreme heat and to the amount of vegetation measurements that needed to be done. In addition, at that time most birds had either finished nesting or were off their nests searching for food for their nestlings (Maiken Winter, personal observation). The systematic and haphazard walking methods were most efficient early in the day and early in the nesting season, because most females were still egg-laying or incubating. As both the day and the season progress, behavioral observations seemed to be more productive, because most birds were off their nests much of the time. However, these times depend on the species studied and the latitude in which a study is conducted. For example, in Kansas nest density of grassland birds remains high through mid- to late- July, and the sedge wren (*Cistothorus platensis*) and American goldfinch (*Carduelis tristis*) do not even start nesting until July (Elmer J. Finck, personal communication).

The earlier in the nesting cycle a nest is found, the more information it provides in terms of exposure days (Johnson 1979). Therefore, one should strive to find nests as early in the nesting cycle as possible. However, rates of nest abandonment might be higher early in the nesting cycle. In addition, the method by which a nest is found might affect rates of nest abandonment. We tested if rates of nest abandonment of all grassland-nesting bird species combined were dependent on the stage the nest was found in and on the search method, and if interactive effects existed between the stage of the nesting cycle and the nest-search method (PROC CATMOD, SAS 1995). Virtually no nests were abandoned during the nestling stage, so we restricted our analyses to the egg-laying and incubation stages. The probability that a nest was abandoned was significantly lower in the incubation than in the egg-laying stage (Chi-Square = 11.4, $P < 0.001$, df = 1, n = 467; Table 1). However, rates of nest abandonment did not vary with nest-searching method (Chi-square = 3.5, $P = 0.48$, df = 4, n = 573), and there was no interactive effect between the nesting stage and search method (Chi-square = 6.43, $P = 0.17$, df = 4, n = 462).

The percentage of nests found during the three stages of the nesting cycle differed greatly among methods and the three focal species (Table 1). Most nests of bobolink and Savannah sparrow were found by behavioral observation during the nestling stage. Fewer nests were found by using the systematic and haphazard walking methods. These nests were found mostly during incubation. As mentioned earlier, bobolink and Savannah sparrow rarely fly directly from their nests but tend to walk considerable distances before flushing. This behavior seems to become more prevalent as a bird invests more time and energy in its nest (i.e., later in the nesting cycle). Therefore, we recommend that the systematic or haphazard walking method be used early during incubation. Later in the breeding season, when nests from all stages are encountered, behavioral observations appear to provide the largest number of nests.

Most nests of clay-colored sparrow were found during incubation, by using the systematic and haphazard walking method (Table 1). Clay-colored sparrow places its nest above ground, and almost always flushes directly from the nest. For this reason, the systematic and haphazard walking methods are more successful during the incubation stage. During the nestling stage, behavioral observations lead to the discovery of most nests.

In summary, our results indicate that observers should vary their nest-searching methods according to the species under study, and the time during the day and the nesting season. Because rates of nest abandonment did not differ among methods, observers do not need to worry about biases in abandonment rates that result from different search methods. In our study areas and for our study species, the best time for nest-searching was between 0600 and 1100, and from the end of May until the end of June. The current concern about grassland birds highlights the importance of understanding their population dynamics and how they respond to management. Key to that understanding is to find and monitor adequate numbers of nests of these elusive species. We hope that our paper will help in achieving this goal.

## ACKNOWLEDGMENTS

We thank all the field assistants that helped to fine-tune and apply the nest-searching methods that we developed during the last 7 years. Thanks to Rolf R. Koford for exchanging ideas in nest-searching, to Pam J. Pietz for introducing us to the stick-sweep method, and to Elmer J. Finck, Dianne A. Granfors, Larry D. Igl, Roz B. Renfrew, John Slotterback, and Peter D. Vickery for useful comments that greatly improved earlier versions of the manuscript.

## LITERATURE CITED

Bent, A. C. 1965. Life histories of North American blackbirds, orioles, tanagers, and allies. Dover Publications, New York, New York.

Bent, A. C. 1968. Life histories of North American cardinals, grosbeaks, buntings, towhees, finches, sparrows, and allies. Dover Publications, New York, New York.

Dechant, J. A., M. L. Sondreal, D. H. Johnson, L. D. Igl, C. M. Zimmerman, and B. R. Euliss. 1998 (revised 2001). Effects of management practices on grassland birds: Le Conte's sparrow. Northern Prairie Wildlife Research Center, Jamestown, North Dakota.

Fondell, T. F., S. T. Hoekman, and I. J. Ball. 2000. Locating nests of birds in grasslands from a mobile tower blind. Prairie Naturalist 32:201-208.

Higgins, K. F., L. M. Kirsch, and I. J. Ball, Jr. 1969. A cable-chain device for locating duck nests. Journal of Wildlife Management 33:1009-1011.

Johnson, D. H. 1979. Estimating nesting success: the Mayfield method and an alternative. Auk 96:651-661.

Johnson, D. H., and L. D. Igl (Series Coordinators). 2001. Effects of management practices on grassland birds. Northern Prairie Wildlife Research Center, Jamestown, North Dakota: Northern Prairie Wildlife Research Center Home Page. http://www.npwrc.usgs.gov/resource/literatr/grasbird/grasbird.htm

Klett, A. T., H. F. Duebbert, C. A. Faanes, and K. F. Higgins. 1986. Techniques for studying nesting success of ducks in upland habitats in the Prairie Pothole Region. U.S. Fish and Wildlife Service, Resource Publication 158. http://www.npwrc.usgs.gov/resource/tools/nest/nest.htm

Koford, R. R. 1999. Density and fledging success of grassland birds in Conservation Reserve Program fields in North Dakota and west-central Minnesota. Pp. 187-195 *in* Ecology and conservation of grassland birds of the western hemisphere (P. D. Vickery and J. R. Herkert, editors). Studies in Avian Biology 19.

Lokemoen, J. T., and J. A. Beiser. 1997. Bird use and nesting in conventional, minimum-tillage, and organic cropland. Journal of Wildlife Management 61:644-655.

Martin, T. E., and G. R. Geupel. 1993. Nest-monitoring plots: methods for locating nests and monitoring success. Journal of Field Ornithology 64:507-519.

Martin, T. E., C. R. Paine, C. J. Conway, W. M. Hochachka, P. Allen, and W. Jenkins. 1997. BBIRD Field Protocol. Montana Cooperative Wildlife Research Unit, University of Montana, Missoula, Montana, USA. [http://pica.wru.umt.edu/BBIRD/protocol/dataform.htm; date accessed: January 23, 2002].

Peterjohn, B. G., and J. R. Sauer. 1999. Population status of North American grassland birds from the North American Breeding Bird Survey, 1966-1996. Pp. 27-44 *in* Ecology and conservation of grassland birds of the western hemisphere (P. D. Vickery and J. R. Herkert, editors). Studies in Avian Biology 19.

Rivers, J. W., D. P. Althoff, P. S. Gipson, and J. S. Pontius. 2003. Evaluation of a reproductive index to estimate dickcissel reproductive success. Journal of Wildlife Management 67:136-143.

SAS Institute, Inc. 1995. SAS/STAT User's Guide, Release 6.03 edition. SAS Institute, Cary, North Carolina.

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. Journal of Wildlife Management 47:893-901.

Vickery, P. D., M. L. Hunter, and J. V. Wells. 1992. Use of a new reproductive index to evaluate relationship between habitat quality and breeding success. Auk:109:697-705.

Winter, M. 1999. Nesting behavior and nesting success of Henslow's sparrows and dickcissels in southwestern Missouri prairie fragments. Wilson Bulletin 111:515-527.

Winter, M., D. H. Johnson, T. M. Donovan, and W. D. Svedarsky. 1998. Evaluation of the Bird Conservation Area Concept in the northern tallgrass prairie. Annual Report for the U.S. Department of the Interior, U.S. Geological Survey, Northern Prairie Wildlife Research Center, Jamestown, North Dakota. http://www.npwrc.usgs.gov/resource/1999/bcarprt/bcarprt.htm

Winter, M., and J. Faaborg. 1999. Varying patterns of "area-sensitivity" in grassland-nesting birds. Conservation Biology 13:1424-1434.

Winter, M., D. H. Johnson, J. A. Dechant, T. M. Donovan, and W. D. Svedarsky. 1999. Evaluation of the Bird Conservation Area Concept in the northern tallgrass prairie. Annual Report for the U.S. Department of the Interior, U.S. Geological Survey, Northern Prairie Wildlife Research Center, Jamestown, North Dakota. htttp://wwww.npwrc.usgs.gov/resource/2000/bcact/bcact.htm

Winter, M., D. H. Johnson, T. M. Donovan, and W. D. Svedarsky. 2000. Evaluation of the Bird Conservation Area Concept in the northern tallgrass prairie. Annual Report for the U.S. Department of the Interior, U.S. Geological Survey, Northern Prairie Wildlife Research Center, Jamestown, North Dakota. http://www.npwrc.usgs.gov/resource/2001/bca2000/bca2000.htm

Winter, M., D. H. Johnson, J. A. Dechant, T. M. Donovan, and W. D. Svedarsky. 2001. Evaluation of the Bird Conservation Area Concept in the northern tallgrass prairie. Annual Report for the U.S. Department of the Interior, U.S. Geological Survey, Northern Prairie Wildlife Research Center, Jamestown, North Dakota. http://www.npwrc.usgs.gov/resource/2002/bca2001/bca2001.htm

*Received: 13 May 2002* *Accepted: 13 July 2003*