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FLORIDA GRASSHOPPER SPARROW REPRODUCTIVE SUCCESS BASED ON NESTING RECORDS

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Abstract.—Estimated reproductive success of Florida Grasshopper Sparrows (*Ammodramus savannarum floridanus*) obtained by monitoring nests is unknown. This paper represents the first study of reproductive success based on nesting records for this endangered subspecies. We located 13 nests during the 1996 breeding season and found an active nest up to eight weeks later than any previously recorded egg date. Using the Mayfield method, nest success was calculated to be 0.11 at Avon Park Air Force Range in Highlands and Polk counties, and 0.33 for Three Lakes Wildlife Management Area in Osceola County. Annual productivity per pair was estimated to be between 1.4 and 1.7 fledglings at Avon Park Air Force Range, and between 4.3 and 5.4 fledglings at Three Lakes Wildlife Management Area. No nests were found at the National Audubon Society's Ordway-Whittell Kissimmee Prairie Sanctuary in Okeechobee County. We estimated that two of the three populations we studied did not produce enough young to maintain current population levels. Predation was the major cause of nest failure during 1996. Our results give reason to be seriously concerned about the long-term viability of this endangered subspecies.

In recent years, interest in grassland bird conservation has increased as populations have declined. Peterjohn and Sauer (1993) estimated that grassland birds have experienced greater population declines than any other ecological group of birds in the United States. Grasshopper Sparrow (*Ammodramus savannarum*) populations have severely declined in recent decades (Robbins et al. 1986). The Florida Grasshopper Sparrow (*A. s. floridanus*), is an endemic, sedentary subspecies that inhabits the native dry prairie of central Florida. It is listed as endangered by the State of Florida (Kale 1978), and by the United States Fish and Wildlife Service (Federal Register 1986). By 1995, 88% of the prairie habitat in central Florida had been converted to other uses, primarily improved pasture and citrus plantations (Shriver 1996). At present, there are only four sites where Florida Grasshopper Sparrows are known to breed. The state of Florida recently acquired the Kissimmee Prairie State Preserve in Osceola and Okeechobee counties; Florida Grasshopper Sparrows are known to

breed at this site, but reproductive rates and population numbers are unknown. Because the breeding distribution of this endangered taxon appears to be small and fragmented, it is critical to determine whether rates of reproductive success are sufficient to maintain present population levels at sites where it occurs, or conversely, whether any of these sites are acting as population sinks (Pulliam 1988).

Florida Grasshopper Sparrow nests are very difficult to find. The domed ground nest is well concealed, usually in dense grass and shrubs. For example, a three-year study on Florida Grasshopper Sparrow breeding ecology and habitat selection failed to locate a single nest (W. G. Shriver, pers. comm.). Not surprisingly, there is very little information on the reproductive success of Grasshopper Sparrows based on nest observations, and there is essentially no information on the endangered Florida subspecies (Vickery 1996). Few estimates of reproductive success based on nesting records for any subspecies of Grasshopper Sparrows have been reported in the literature. Kershner and Bollinger (1996) estimated reproductive success to be 41% for the eastern subspecies (*A. s. pratensis*) in Illinois; Patterson and Best (1996) estimated a 30% success rate for *A. s. pratensis* in Iowa; Johnson and Temple (1990) estimated nest-day survival ranged from 0.750 to 0.947 (nest success rate was calculated to be 0.2% to 31.9% based on 21-day nesting cycle) for *A. s. perpallidus* in Minnesota; and Wray et al. (1982) estimated reproductive success to be 47%, 8%, and 7% for 1978, 1979, and 1980 respectively, for *A. s. pratensis* in West Virginia. Other estimates of reproductive success (Vickery et al. 1992a) have used an index based on behavioral observations. Using this index, Delisle and Savidge (1996) estimated a reproductive success rate of 52% for the eastern subspecies in southeastern Nebraska; Collier (1994) estimated 65% and 92% success rates for the western subspecies (*A. s. perpallidus*) in California in 1992 and 1993, and Vickery et al. (1992a) estimated 40 to 50% success rate for the eastern subspecies in southwestern Maine. This study reports the first reproductive success rates for Florida Grasshopper Sparrows based on nests found in 1996. Although our sample size was smaller than the minimum of 20 suggested by Hensler and Nichols (1981) to achieve a minimum precision in the estimator, this paper provides valuable new information given the lack of published data on the reproductive success of Florida Grasshopper Sparrows and the great difficulty in finding nests.

We recognize that this study is based on only one year of data and may not reflect broader multi-year patterns. However, preliminary analysis of an index of reproductive success based on behavioral observations (Vickery et al. 1992a) has shown that 1996 indices (Vickery and Perkins 1997) are similar to indices recorded by Shriver (1996) from 1993 to 1995. Therefore, we think that these data may reflect

broader multi-year patterns of Florida Grasshopper Sparrow productivity.

STUDY SITES AND METHODS

Two study sites were used for this study: Avon Park Air Force Range in Highlands and Polk Counties (27°37'N 81°19'W), and Three Lakes Wildlife Management Area in Osceola County (27°47'N 81°06'W). These sites will be referred to as "Avon Park" and "Three Lakes," respectively. A third potential site for this study, Ordway-Whittell Kissimmee Prairie Sanctuary in Okeechobee County (27°34'N 80°58'W), hereafter referred to as "Kissimmee Prairie," was artificially flooded during much of the 1996 breeding season. No nests were found at Kissimmee Prairie, we estimated that this site had extremely low reproductive rates based on reproductive indices from an associated study, and we saw only three fledglings at this site during the entire 1996 breeding season (Vickery and Perkins 1997). The three sites are less than 30 km from each other.

Native dry prairie is characterized as flat, unforested, fire-dependent grasslands with scattered shrubs. Dominant graminoids include wiregrass (*Aristida beyrichiana*), toothache grass (*Ctenium aromaticum*), bluestem (*Andropogon spp.*), and beak rush (*Rhynchospora spp.*); dominant shrubs include saw palmetto (*Serenoa repens*), dwarf oak (*Quercus minima*), fetterbush (*Lyonia lucida*), and gallberry (*Ilex glabra*); dominant forbs include bachelor's button (*Polygala spp.*), yellow-eyed grass (*Xyris spp.*), hat pin (*Eriocaulon decangulare*), meadow beauty (*Rhexia spp.*), and a variety of milkweeds, orchids, and asters (Shriver 1996).

Nests were found during the 1996 breeding season, between 4 April and 28 August. Florida Grasshopper Sparrow nests were located opportunistically as we conducted spot-mapping surveys and completed vegetation measurements for an associated study. Nests were usually found after flushing birds from the nest or after watching them land in a location with food. After nests were located, they were marked with flags 3 m from the nest, and were checked every one to six days ($\bar{x} = 2.9$). Mean clutch size was calculated.

We used Mayfield's (1961, 1975) method to determine nest survival rates and Johnson's (1979) formula to calculate standard deviations. The traditional estimate of reproductive success divides the number of successful nests by the number of observed nests and usually overestimates actual nest survival (Mayfield 1961, 1975). The Mayfield method adjusts for this bias, and was the best method for our study because periods between visits to the nest were short and the sample size was small (Johnson 1979), and the causes of mortality were relatively constant, not catastrophic (Klett and Johnson 1982, Johnson and Shaffer 1990). The Mayfield method is the only method to make studies comparable when there is more than one cause of nest loss (Beintema 1992). Nest losses involved only whole-brood losses. To calculate when a nest was lost, losses were assumed to have occurred at the midpoint between two visits. Nests were considered successful if young were expected to leave the nest between nest visits, and if, on a later visit, the nest was found empty with no evidence of disturbance. Best and Stauffer (1980) noted that snake and avian depredation may occur in the final days of the nestling period and go unnoticed, which could potentially result in an overestimate of nesting success; we had only one nest where this might have occurred.

We used Austin's (1977) method of determining the number of nesting attempts per year. With this method, populations with greater nest success rates have fewer total nest attempts than populations with lower success rates. This is because a successful nest attempt requires more days (occupies a larger percentage of the length of the breeding season) than an unsuccessful attempt. We combined Austin's method with Pinkowski's (1979) estimator of annual productivity to determine whether Florida Grasshopper Sparrow breeding success was sufficient to maintain current population levels at each

study site. All breeding-success and productivity calculations assume that there is an equal likelihood of locating each nest.

The duration of the incubation period for this subspecies is reported as 11 to 13 days (Nicholson 1936, Smith 1968, Vickery 1996), the nestling stage is reported as approximately nine days (Smith 1968, Vickery 1996), and egg laying usually averages four days. Behavioral observations of known territories indicate that the length of time between the fledging of a successful nest and laying of the first egg in the next clutch is 10 to 17 days, and that 3 to 4 days are thought to elapse between the failure of a nest and production of the first egg in the subsequent attempt (Vickery unpubl. data). We used 13.5 days and 3.5 days for the above two periods to estimate the number of nesting attempts. A nest was judged successful if at least one nestling survived to leave the nest.

We tried to determine the cause of failed nests. Failed nests that were left empty but intact were thought to be the result of snake or avian predators, and failed nests that were obviously disturbed or contained eggshell fragments were thought to be the result of mammalian predators (Rearden 1951, Best 1978). At each visit we also noted the presence or absence of fire ants (*Solenopsis invicta*) at the nest.

RESULTS

We found 13 nests during the 1996 breeding season (Appendix 1). Eight nests were found at Avon Park, and five at Three Lakes. Active nests were found as early as 3 May and as late as 19 August. Mean clutch size was 3.3 (SD = 0.5; n = 7) at Avon Park, and 3.0 (SD = 0.0; n = 2) at Three Lakes (Table 1). These clutch sizes were similar to the clutch size of 3.7 ± 0.5 previously reported for Florida Grasshopper Sparrows (McNair 1986), but were lower than clutch sizes reported for the eastern subspecies in West Virginia 4.1 ± 0.8 to 4.5 ± 0.6 (Wray et al. 1982), and 4.4 in Michigan (Walkinshaw 1940).

Daily survival rate for nests was 0.90 at Avon Park and 0.95 at Three Lakes. With a nesting cycle length of 21 days (12 days incubation and 9 days of nestling stage), we calculated the nest success rate over the entire nesting cycle to be 0.11 at Avon Park and 0.33 at Three Lakes (Table 1).

Table 1. Florida Grasshopper Sparrow nesting estimations derived from eight nests at Avon Park Air Force Range, Florida and five nests from Three Lakes Wildlife Management Area, Florida, during the 1996 breeding season.

Estimation	Avon Park Air Force Range Mean (± 1SD)	Three Lakes Wildlife Management Area Mean (± 1SD)
Daily Nest Survival	0.90 (0.87-0.94)	0.95 (0.91-0.98)
Total Nest Survival	0.11 (0.05-0.26)	0.33 (0.15-0.71)
Fledglings/Successful Nest	3.00 (3.00-3.00)	3.33 (2.18-4.48)
Potential Nest Attempts/Season	5.73	3.94
Productivity/Pair	1.98	4.28
Productivity (4 attempts)	1.38	4.34
Productivity (5 attempts)	1.72	5.43

We found an active nest with eggs on 19 August 1996. This represents the latest egg record for Florida Grasshopper Sparrows by more than eight weeks (Stevenson and Anderson 1994). If one assumes the clutch from this nest hatched on the day of discovery, the nestlings would not fledge until at least 28 August. Given that the earliest reported egg date for Florida Grasshopper Sparrows is 21 March (McNair 1986), Florida Grasshopper Sparrows have a breeding season that can potentially extend for 160 days. Assuming a 160-day breeding season, we estimated the potential number of nest attempts per season at Avon Park to be 5.7, because nest success was so poor. (We calculated this by using 13.5 days between fledging of a successful nest and the first egg of the next attempt and 3.5 days between the failure of a nest and the first egg of the next attempt.) At Three Lakes nest success was better; consequently, the estimated number of total nest attempts was lower (3.9). The number of young fledged per successful nest was 3.0 at Avon Park and 3.3 at Three Lakes. Thus, we estimated annual productivity per pair to be 2.0 at Avon Park and 4.3 at Three Lakes (Table 1).

We think that the actual number of total nest attempts per season falls somewhere between the estimates for Avon Park and Three Lakes. We used an estimate of five nest attempts to estimate annual productivity to be 1.7 fledglings at Avon Park and 5.4 fledglings at Three Lakes. Using a conservative estimate of four total nest attempts, we estimated an annual productivity of 1.4 fledglings at Avon Park, and 4.3 fledglings at Three Lakes (Table 1). Thus, the actual annual productivity per pair was probably somewhere between the two figures given for each site.

Delany et al. (1993) calculated a 59.8% adult annual survival rate, and we projected a 14.8% to the first breeding season for Florida Grasshopper Sparrows (fledgling survival = 25% of adult survivorship; see Ricklefs 1977). Using these estimates, a pair would need to produce 5.5 fledglings annually to maintain a stable population.

To produce 5.5 fledglings, assuming 0.11 and 0.33 for nest survival rates and 3.0 and 3.3 fledglings per successful nest at Avon Park and Three Lakes, respectively, it would be necessary for each pair to attempt nesting 16 times at Avon Park, and 5 times at Three Lakes [5.5 fledglings/(fledglings per successful nest)(nest success rate)]. This is inconceivable at Avon Park, but may be possible at Three Lakes.

Thus, we conclude that Florida Grasshopper Sparrow populations, even under the most optimistic estimations, were not replacing themselves at Avon Park or Kissimmee Prairie during the 1996 breeding season. Reproduction at Three Lakes was probably sufficient to sustain current population levels, but probably provided few, if any, surplus individuals. In addition, preliminary work by Vickery and Perkins (1997) suggests that adult annual survival rates may be lower than the previous 59.8% estimate (Delany et al. 1993).

Of the failed nests (n = 9) that we monitored in 1996, predation was the major cause of nest failure (88%), and one nest was abandoned. Of the eight depredated nests, two (25%) were probably destroyed by mammals and six (75%) by snake or avian predators.

In Michigan, Walkinshaw (1940) observed small red ants attacking young birds in a nest and entering pipped eggs, and the adult female ate all ants in and around the nest. Introduced fire ants have been reported to have a negative impact on Northern Bobwhite (*Colinus virginianus*) populations in Texas (Allen et al. 1995), and Travis (1938) reported 6.5% loss of pipping Northern Bobwhite chicks to fire ants *(Solenopsis geminata)* in northern Florida. However, in 55 visits to 13 nests, we found no evidence of fire ant predation during the 1996 breeding season.

Discussion

Our data suggest that two of our three sites acted as sink populations during the 1996 breeding season. This could be critical for an endangered taxon that is short lived, apparently sedentary, and is known to be breeding at only four locations. Small populations may breed at some unprotected sites, but these sites may have limited value to the viability of the taxon.

The sizable population found at Avon Park during the 1996 breeding season (>70 pairs) may be the result of the reproductive surplus of some other source population in 1995. If this is the case, a substantial majority of the known Florida Grasshopper Sparrow population occurred in sink habitat. Thus, the destruction of a relatively small area of high quality habitat (the source habitat) could lead to population extinction at several sites (Pulliam 1988). If Avon Park and Kissimmee Prairie continue to act as sink populations, Florida Grasshopper Sparrows could only continue to persist at these two sites if Three Lakes, or some other site, acted as a source, and the surplus individuals dispersed to Avon Park and Kissimmee Prairie. However, to date, dispersal between sites has not been documented.

Our estimate of a 160-day breeding season extends the reported breeding season for Florida Grasshopper Sparrows beyond late July (McNair 1986) to late August. We monitored five nests that were at least four weeks later than the previous latest egg record (Stevenson and Anderson 1994). Interestingly, four of these nests were located in areas that were not burned during the summer of 1996 (see Shriver et al. 1996). It appears that the extension of the breeding season applies not only to summer burned areas, but at least occasionally to areas that have not been burned in the summer.

Grasshopper Sparrows can produce ≥ two broods per year in Maine (Vickery et al. 1992a), and D. J. Nicholson (*in* Smith 1968) reported

that Florida Grasshopper Sparrows had three nest attempts. Our study suggests that multiple nest attempts, probably 4 to 5 times annually, are essential for this taxon to survive.

Predation is considered to be the most common cause of nest failure for many songbirds (Martin 1992), and W. H. Nicholson (1936 *in* Smith 1968) notes high nest depredation rates of Florida Grasshopper Sparrows, "I have found 25 to 30 nests under construction; upon returning later I found practically all of them destroyed." Wray et al. (1982) found that snakes (*Coluber constrictor constrictor*) and American Crows (*Corvus brachyrhynchos*) were the major predators (78%) of grassland bird nests in West Virginia. Feral hogs (*Sus scrofa*), spotted skunks (*Mephitis mephitis*), striped skunks (*Spilogale putorius*), and Loggerhead Shrikes (*Lanius ludovicianus*) have all been documented to be a threat to Florida Grasshopper Sparrows or their nests (Smith 1968, T. F. Dean unpubl. data). An additional 11 bird species, 8 mammalian species, and 12 snake species are present in the dry prairie of Florida and could potentially be predators of Florida Grasshopper Sparrows and their nests.

Florida Grasshopper Sparrow nests are extremely well concealed, and are hard to detect by human investigators (pers. obs). Yet concealment only affects predators that depend on sight, and does not influence vulnerability of nests to snake predation (Best 1978). Also, nest concealment may not be a factor when predators locate nests incidentally when searching for other prey types (Vickery et al. 1992b); Wray et al. (1982) found that well concealed Grasshopper Sparrow nests suffered higher predation rates than more open nests of the Vesper Sparrow (*Pooecetes gramineus*).

We think the rates of nest predation we observed were not artificially inflated by our activities at the nests. Because our study sites had extensive human activity throughout the breeding season, human scent was scattered over the entire study area, and scent trails would be of little use to mammalian predators. Nest flags would not likely have provided clues to visual predators such as American Crows because the same flags were used to mark 50-m grids across almost the entire study area.

In 1996, we estimated that only 11% of nests at Avon Park and 33% of nests at Three Lakes were successful; there was essentially no reproductive success at Kissimmee Prairie. In 1993, Florida Grasshopper Sparrow reproductive success was estimated to be less than 25% (Vickery 1996). Given this generally low annual productivity, it seems unlikely that populations at Avon Park and Kissimmee Prairie were sustaining themselves in 1996. Only one of our study sites, Three Lakes, appears to have sufficient rates of recruitment to maintain populations through local recruitment. The above estimates, combined

with the short lifespan of this species, give reason to be seriously concerned about the long-term viability of this endangered subspecies.

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Appendix 1. Nest records for 13 Florida Grasshopper Sparrow (*Ammodramus savannarum floridanus*) nests during the 1996 breeding season.

Nest #	Site[a]	Date	Eggs	Young	Age[b]	Presumed Outcome
1	AP	3 May	3	0		
		5 May	3	0		
		8 May	3	0		
		13 May	0	0		Avian/Snake Depredation[c]
2	AP	7 June	4	0		
		10 June	4	0		
		13 June	4	0		
		16 June	4	0		
		19 June	0	3	2	
		22 June	0	3	5	
		25 June	0	3	8	
		28 June	0	0		Successful
3	TL	20 June	3	0		
		24 June	3	0		
		27 June	2	0		Abandoned[d]
4	TL	20 June	3	0		
		24 June	3	0		
		27 June	0	0		Mammalian Depredation[e]
5	AP	1 July	1	0		
		4 July	4	0		
		5 July	4	0		
		8 July	0	0		Mammalian Depredation
6	TL	2 July	2	2	1	
		5 July	0	4	4	
		8 July	0	4	7	
		11 July	0	0		Successful
7	AP	4 July	2	0		
		7 July	3	0		
		10 July	3	0		
		12 July	3	0		
		15 July	1	2	2	
		17 July	0	0	4	Avian/Snake Depredation
8	TL	5 Jul	1	2	1	
		8 Jul	1	2	4	
		11 Jul	1	2	7	
		15 Jul	1	0		Successful
9	AP	17 Jul	1	0		
		20 Jul	3	0		
		23 Jul	3	0		
		25 Jul	3	0		
		28 Jul	3	0		
		30 Jul	0	0		Avian/Snake Depredation

[a]Age = Estimated age of nestling (days).
[b]AP = Avon Park Air Force Range, TL = Three Lakes Wildlife Management Area.
[c]Avian or snake depredation presumed.
[d]Nest abandoned, 1 egg was missing, 2 eggs fertile, but broken.
[e]Mammalian depredation presumed.

Appendix 1. (Continued) Nest records for 13 Florida Grasshopper Sparrow (*Ammodramus savannarum floridanus*) nests during the 1996 breeding season.

Nest #	Site[a]	Date	Eggs	Young	Age[b]	Presumed Outcome
10	AP	18 Jul	0	3	3	
		20 Jul	0	0		Avian/Snake Depredation
11	TL	23 July	0	4	3	
		29 July	0	4	9	
		5 Aug	0	0		Successful
12	AP	5 Aug	2	0		
		8 Aug	3	0		
		11 Aug	3	0		
		14 Aug	3	0		
		16 Aug	3	0		
		19 Aug	0	0		Avian/Snake Depredation
13	AP	19 Aug	3	0		
		21 Aug	3	0		
		22 Aug	0	0		Avian/Snake Depredation

[a]Age = Estimated age of nestling (days).
[b]AP = Avon Park Air Force Range, TL = Three Lakes Wildlife Management Area.
[c]Avian or snake depredation presumed.
[d]Nest abandoned, 1 egg was missing, 2 eggs fertile, but broken.
[e]Mammalian depredation presumed.

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