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The Journal of Wildlife Management, Vol. 59, No. 4. (Oct., 1995), pp. 752-758.

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Received 15 December 1993.
Accepted 28 February 1995.
Associate Editor: Conroy.

SPATIAL ANALYSIS OF SANDHILL CRANE NESTING HABITAT

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Abstract: Ecologists need to understand how species' habitat requirements change across spatial scales, and how scale influences spatial analyses across heterogeneous landscapes. We used a geographic information system (GIS) to analyze nesting greater sandhill crane (*Grus canadensis tabida*) use of habitat at multiple spatial scales. We collected data on a 11,487-ha portion of Seney National Wildlife Refuge (NWR), Michigan, during 1984–87. Percent composition of 17 habitat variables (4 upland classes, 6 wetland classes, 6 water regimes, and total wetland) was compared around nest sites and random points for 5 circular buffers with radii of 50, 100, 200, 419, and 709 m. Cranes selected ($P < 0.01$) nest sites in or near seasonally flooded emergent (nonwoody) wetlands and avoided ($P < 0.01$) forested uplands. There was no ($P > 0.01$) habitat selection beyond 200 m from a nest. Beyond this distance our analysis was inconclusive, in part, because larger buffer scales increased heterogeneity and overlap among nest and random buffers. Observers should consider scale of analysis when investigating spatial patterns of use of habitat.

J. WILDL. MANAGE. 59(4):752–758

Key words: geographic information system, greater sandhill crane, *Grus canadensis tabida*, habitat selection, heterogeneity, Michigan, nesting, spatial scale.

Wildlife managers should understand how species' habitat requirements change across spatial scales, and how scale influences spatial analyses across heterogeneous landscapes (Wiens 1986, 1989; Morris 1987; Counc. Environ. Qual. 1993; Berstein and Goldfarb 1995). Our knowledge of habitat requirements is often based on single scale comparisons of resource use and availability for a given species. For example, studies of ground-nesting birds often focus on habitat characteristics measured at the nest site. While this focus has provided valuable information about nesting materials, nest success, and predation, comparisons at larger scales are needed to quantify resource use beyond the nest site. Past research may have been limited to small-scale approaches because of a lack of large-scale habitat data and the complex computational requirements of spatial analyses. Some investigators have used GIS to describe heterogeneity and scale effects in complex landscapes (Johnson 1990, Lehmkuhl and Raphael 1993, Stow 1993).

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We used GIS to investigate scale-dependent patterns of use of habitat in a nesting population of sandhill cranes. Loss of wetlands and focus on their delineation have re-emphasized the importance of understanding the needs of wetland-dependent species at multiple scales. Sandhill cranes are often used as indicators of ecosystem health in wetlands because they mate for life, exhibit fidelity to nesting territories, and defend territories against conspecifics (Walkinshaw 1989). Our objectives were to evaluate habitat selection of nesting greater sandhill cranes at multiple spatial scales and to assess our ability to detect scale-dependent patterns of use of habitat in a heterogeneous landscape. Specifically, we used a multiscale GIS approach to compare habitat composition around crane nests and random points.

We thank A. H. Farmer, T. J. Keldsen, N. B. Kotliar, J. A. Sedgwick, T. R. Stanley, D. F. Stauffer, and R. P. Urbanek for reviewing the manuscript. S. L. Haire assisted with GIS.

STUDY AREA

We collected data during 1984–87 on a 11,487-ha portion of Seney NWR, located in the Great Manistique Swamp of Michigan's Upper Peninsula (McMillen 1988, Urbanek and Bookhout 1992). The landscape was a heterogeneous mosaic of wetland and upland habitat, including 2,800 ha of open water in 26 pools, several of which were drawn down by refuge personnel during the summer. Our GIS analysis (described below) indicated 38% of the area was upland and 62% was wetland. Forests covered 84% of the uplands and contained pines (*Pinus* spp.), quaking aspen (*Populus tremuloides*), and paper birch (*Betula papyrifera*). Emergents covered 43% of the wetlands and contained cattail (*Typha latifolia*), sedges (*Carex* spp.), and bullrushes (*Scirpus* spp.).

METHODS

Spatial Scale

We compared percent habitat composition around crane nests (used) and random points (available) at 5 spatial scales using a GIS (Fig. 1). We first made comparisons on a scale of perceived biological importance to nesting cranes. McMillen (1988) used telemetry to determine the home range of 8 prefledged crane chicks at Seney NWR. Using the harmonic mean method of Samuel et al. (1985), she found an average chick home range (95% use distribution) of 157.9 ha with an average core area of 55.1 ha. Conversion to circular buffers yields analysis areas with radii of 709 and 419 m, respectively, which we used to approximate crane territory size during nesting (data on territory size defended by adults were not available; actual crane territories or home ranges may be irregularly shaped).

Preliminary analyses at these territory scales revealed possible scale-dependent interactions among grain size (habitat polygons, defined below), scale of analysis (buffer size), and extent (study area) (Allen and Hoekstra 1991). To further explore these interactions, we arbitrarily selected additional radii of 50, 100, and 200 m (0.8, 3.1, and 12.6 ha, respectively) for analysis. We selected only smaller scales because larger buffers would exacerbate scale-dependent problems. To account for the spatial distribution of habitat polygons, we compared composition of nest buffers with random buffers, rather than with composition of the entire study area.

Nest Sites and Random Points

We used helicopter (1985–87) and ground searches (1984–87), and followed radio-marked birds, to locate crane nests (McMillen 1988). We did not consider upland areas >16 ha and open water pools suitable nesting habitat (Walkinshaw 1965, Drewien 1973) and did not search them.

We evaluated 54 nests (after excluding 5 nests that were in unmapped areas) that were active during ≥1 year of the 4-year study. Although nest locations varied from year to year for many pairs, they were not independent among years because pairs often returned annually to nest in the same territory. Consequently, we minimized bias by pooling across years. Thus, for nests within the same territory, habitat composition for nest buffers represented an average of all sites chosen by a particular crane pair during the study. This method yielded a sample of 37 crane pairs from the 54 nest locations.

We used GIS to locate 59 random points (to balance sample size with the 59 nests in the original dataset) in the study area. Because we compared used and available habitat (instead of used and unused), we allowed random points to occur anywhere in suitable nesting habitat, including nest territories but excluding lakes and large (>16 ha) upland blocks. We did not use nest sites or random points for analysis if >5% of the buffer area contained unmapped habitat;

thus, nest and random sample size decreased with increasing buffer size.

GIS Analysis

We mapped habitat into separate polygons (areas containing similar vegetation or water regime) using 1:12,000, color, infrared, aerial photographs taken 2 August 1985. The 4 upland classes, with percent composition of the study area in parentheses, were forested (32), shrubland (4), grassland (1), and badland (1). We mapped wetlands into 6 classes and 6 water regimes, respectively: emergent (27), scrub-shrub (16), unconsolidated bottom (10), forested (8), aquatic bed (2), and unconsolidated shore (1); seasonally flooded (36), intermittently exposed (11), saturated (10), semipermanently flooded (4), temporarily flooded (1), and permanently flooded (1). Wetland classes and water regimes followed the National Wetland Inventory (NWI) system, although mapping was more detailed than nationwide standards (Cowardin et al. 1979). The minimum mapping unit (grain size) was 0.81 ha for uplands and forested and scrub-shrub wetlands; it was 0.10 ha for all other wetlands. We digitized the study area boundary, 4,178 wetland polygons, 2,865 upland polygons, 54 nest site locations, and 59 random point locations into separate theme coverages and used a vector-based GIS (ARC/INFO) for analysis.

Statistical Analysis

To evaluate selection, we compared percent composition of the 17 habitat variables (4 upland classes, 6 wetland classes, 6 water regimes, and total wetland) around each crane nest and random point at 5 spatial scales. Percent composition values were treated as repeated measures (Looney and Stanley 1989) because buffers were nested within one another (Fig. 1), creating dependent observations (Lehmkuhl and Raphael 1993). To evaluate scale effects among buffers, we tested for interaction between differences in buffer size and differences between nest and random locations (independent variables) using a multivariate approach based on O'Brien and Kaiser (1985). Once we identified significant ($P < 0.05$) habitat variables, we made 20 paired comparisons of buffer sizes for nest and random locations to determine which buffers differed (Looney and Stanley 1989). To assess significance of these multiple comparisons, we used Bonferroni simultaneous probability values (Miller 1966) of 0.01 ($P = 0.05/5$ scales) to compare habitat composition around nest and random locations by buffer and 0.0025 ($P = 0.05/20$) to make 20 paired comparisons of buffer sizes by nest and random locations. We also compared the spatial distributions (bivariate X and Y coordinates) of nest and random locations to identify possible patterns (clumped distributions).

We made all statistical comparisons with multiresponse permutation procedures (MRPP) to test for distributional differences (Biondini et al. 1988, Mielke 1991). We used procedures in program BLOSSOM (Slauson et al. 1991) and reported the standardized test statistic as T. We used MRPP (Euclidean distance statistics) instead of analysis of variance because it has greater power to detect central tendency (median) and dispersion differences among skewed distributions (Mielke and Berry 1994).

RESULTS

Four of 17 habitat variables were important to nesting cranes: total wetland, emergent wetland, seasonally flooded water regime, and forested upland (Fig. 2). Cranes nested in or near ($P < 0.01$) areas with a high percentage of seasonally flooded emergent wetland and away from forested upland. However, differences were only significant within about 200 m of a nest site; beyond this distance, habitat composition did not differ between nest and random. We found no other differences ($P > 0.01$), at any scale, for any of the 13 other habitat components evaluated.

This scaling effect (interaction) can be observed, in the 4 differing habitat variables, by comparing the difference between medians for the 5 buffers (Fig. 2); medians are consistently farther apart for smaller buffers and closer together for larger buffers, indicating apparent habitat selection nearer the nest. Interaction between buffer sizes and differences between nest and random locations (Fig. 2) was confirmed by repeated measures analyses for total wetland ($T = -2.65$, $P = 0.024$), emergent wetland ($T = -2.54$, $P = 0.028$), seasonally flooded water regime ($T = -3.67$, $P = 0.008$), and forested upland ($T = -1.91$, $P = 0.054$). Ten paired comparisons (50 vs. 100 m, 50 vs. 200 m, etc.) of within-random buffers also showed habitat composition around random points was the same ($0.081 \leq P \leq 1.000$ for total wetland, $0.144 \leq P \leq 1.000$ for emergent wetland, $0.075 \leq P \leq 1.000$ for seasonally flooded water regime, and $0.046 \leq P \leq 1.000$ for forested upland) regardless of buffer size. In contrast, 10 within-nest

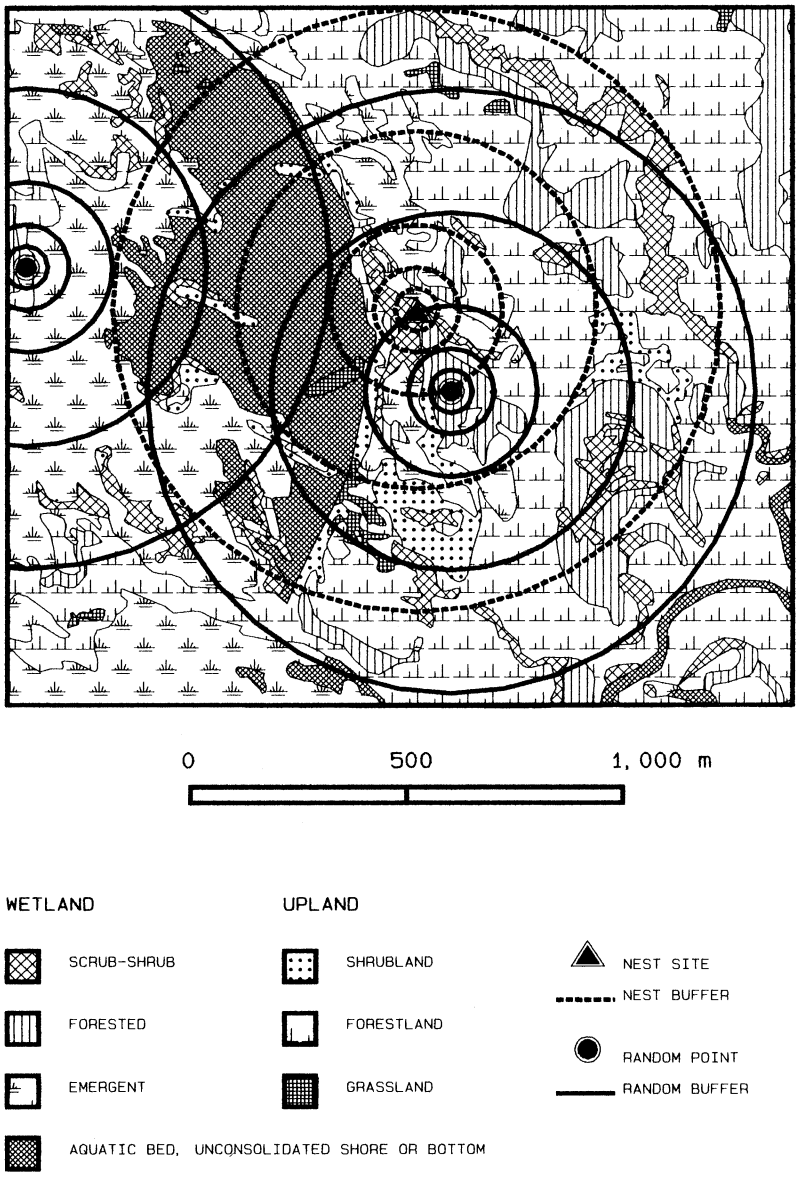

Fig. 1. Example of geographic information system analysis comparing sandhill crane habitat composition around a nest site (no. 33) and 2 random point locations at Seney National Wildlife Refuge, Michigan, 1984–87. Circular buffers have radii of 50, 100, 200, 419, and 709 m. Relative overlap among buffers increases, and likelihood of differences in habitat composition decreases, as buffer size increases.

comparisons showed composition around nest sites was dependent ($0.001 \leq P \leq 0.139$ for total wetland, $0.001 \leq P \leq 0.417$ for emergent wetland, $0.001 \leq P \leq 0.500$ for seasonally flooded water regime, and $0.002 \leq P \leq 0.337$ for forested upland) on size of the buffer, at least for several small versus large buffer comparisons. Comparing spatial distribution of nest sites and random points showed nests were not clumped by area but were distributed randomly in space throughout suitable nesting habitat ($P = 0.789$).

DISCUSSION

Scale and Heterogeneity Effects on Spatial Analysis

Ecologists search for appropriate scales to interpret pattern and process in natural systems.

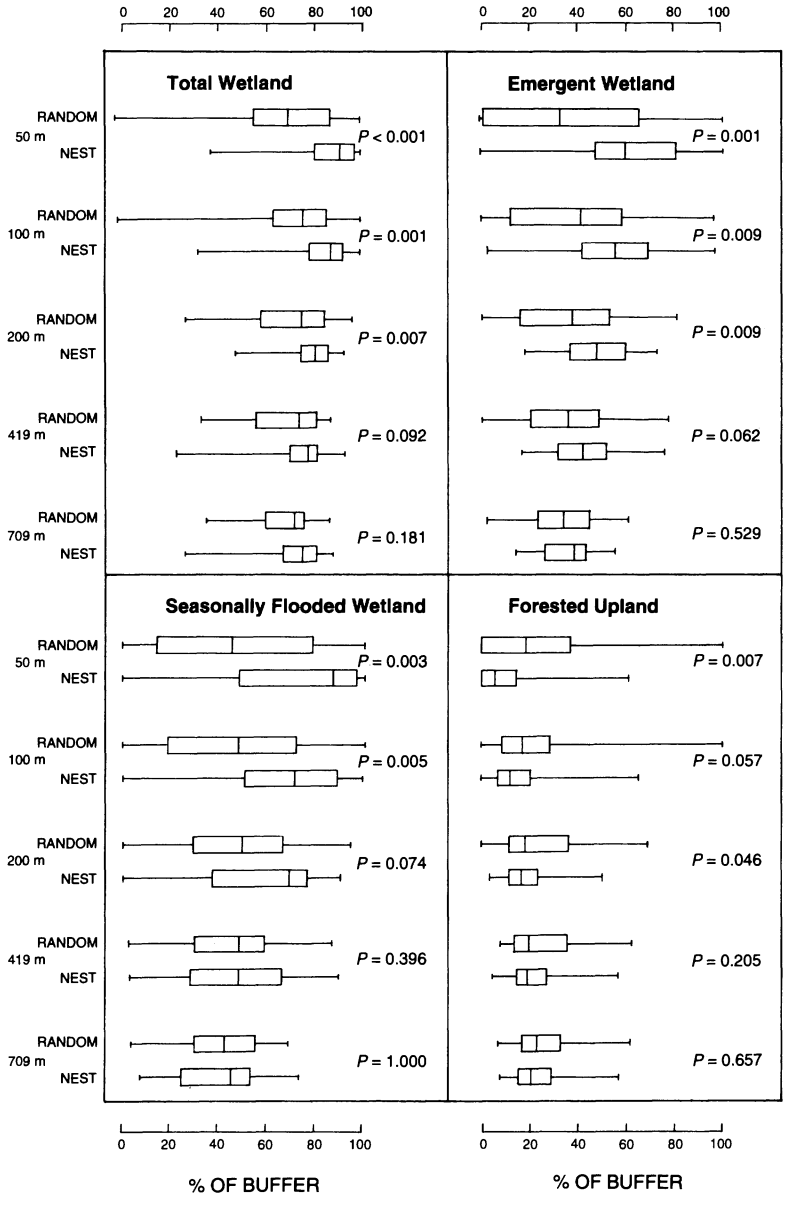

Fig. 2. Box plots comparing habitat composition (% of buffer) around sandhill crane nest sites and random points for 4 variables (total wetland, emergent wetland, seasonally flooded wetland, and forested upland) and 5 spatial scales (circular buffers of 50, 100, 200, 419, and 709 m) at Seney National Wildlife Refuge, Michigan, 1984–87. The difference between medians decreases with increasing buffer size. Each box represents the interquartile range (25th–75th percentiles) with the line inside showing the median (50th percentile). Whiskers at the end of each box show the data range. Number of random points and nest sites, respectively, was 56 and 37 for 50-m buffers, 56 and 36 for 100-m buffers, 56 and 37 for 200-m buffers, 55 and 33 for 419-m buffers, and 49 and 29 for 709-m buffers.

Choosing the wrong scale can lead to the wrong conclusion or to the inability to draw any conclusions. For example, in this study crane nest number 33 (Fig. 1) was actually in a patch of emergent vegetation. Because this patch was smaller than our 0.10-ha grain size, the area was mapped as scrub-shrub wetland, the dominant vegetation of the surrounding patch. Even though a 0.10-ha grain size appears small relative to the entire wetland, it was too large to accurately describe nesting vegetation.

Landscape heterogeneity and scale of analysis influence ability to discern scale-dependent patterns of use of habitat. In our analysis, small

buffers had fewer habitats, so comparisons among small buffers were more likely to show differences than comparisons among large buffers (Fig. 1). Conceptually, sampling habitat using buffer areas is like viewing the landscape through a window, the larger the window the greater the similarity between different views; therefore, heterogeneous landscapes appear more homogeneous at larger scales, minimizing differences among areas (Wiens 1989).

Another concern is increasing scale of analysis (buffer size) relative to a fixed extent (study area). As a greater proportion of the variability within the system is captured as used habitat, the likelihood of detecting differences is reduced (nest and random buffers overlap and compare the same area) (Fig. 1). These interactions may explain why our analyses showed no differences in used and available habitat at larger scales. We may have avoided comparisons of the same area by restricting random point locations to ensure random buffers did not overlap nest buffers. However, comparing used and unused habitat, instead of used and available, creates new problems. As scale of analysis increases and approaches extent, the remaining area of unused habitat approaches zero. Also, it is often difficult to ensure that habitat is really unused; in our case nest searches could have missed some nests.

A third concern is the conundrum of how to bound available habitat, a decision that establishes the specificity of the research question. We limited our analysis by allowing random points to fall only in suitable crane nesting habitat; lakes and large blocks of upland forest were excluded, as were extensive forests in the surrounding region. Clearly, restricting our question to, What habitat within the wetland complex was preferred? rather than What habitat within the region was preferred? increased our chances of better understanding cranes, but decreased our chances of detecting differences (Johnson 1980).

Crane Habitat Selection at Varying Scales

Wetland birds select nesting habitat on the basis of different needs at different scales (Burger 1985). Sandhill cranes nest in emergent wetlands where standing water provides security from nest predators and persistent vegetation provides material to build nests (Urbanek and Bookhout 1992). Our analysis shows the importance of emergent wetlands within a crane territory, at least within 200 m of a nest; beyond that distance our analysis failed to show differences, either because there were none or because they were masked by scaling effects. Clearly, emergent wetland within a territory benefits cranes by increasing foraging and nesting areas. In contrast, cranes did not nest near large blocks of forested upland, possibly because they provided no forage value to cranes or attracted nest predators (Urbanek and Bookhout 1992).

In addition to habitat composition at the time of study, temporal and behavioral patterns may also influence territory acquisition. In our study, although specific nest locations varied 50–600 m among years, mated pairs returned to the same territory annually, precluding selection by other pairs. In addition, some cranes likely selected their territories many years before we collected nest and habitat data. Walkinshaw (1989) found some pairs maintained the same territory for ≤25 years. Initial occupation of a territory may have actually occurred when vegetation, climate patterns, water management, or disturbance levels were different than during our study. Because defended territories may contain several potential nest sites that vary in suitability among years, a nest-centered approach may be inherently weak in detecting patterns of use at larger scales.

MANAGEMENT IMPLICATIONS

As wildlife biologists increase their scale of analysis to search for spatial patterns that explain use of habitat, their ability to detect and interpret these patterns remains scale dependent. We found as scale of analysis increased, relative to a constant study area, there was a corresponding decrease in ability to detect important habitat variables, interpret results, and draw conclusions. Although inconclusive at the larger buffer scales, our analyses showed that cranes prefer seasonally flooded emergent wetlands and avoid forested uplands within their territories. Improving forage quality of upland forests by creating openings or food plots would likely reduce crane territory size and increase nest density at the scale of the entire wetland. However, because management practices that fragment upland forest may be detrimental to other species, they should be cautiously applied to obtain a mosaic effect at appropriate scales.

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Received 20 July 1994.
Accepted 26 May 1995.
Associate Editor: Warner.

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