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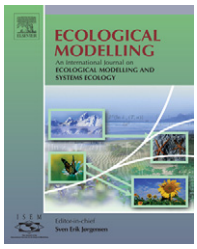

Estimating carrying capacity for sandhill cranes using habitat suitability and spatial optimization models

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ABSTRACT

Northern Ohio supports a small population of greater sandhill cranes (*Grus canadensis tabida*) that is currently listed as state-endangered. Population restoration efforts are currently under consideration, although it is not known if habitats in the state can support additional nesting pairs. Accurate estimates of breeding pair carrying capacity are necessary before conservation efforts can be effectively developed and implemented. We estimated carrying capacity for nesting sandhill cranes using habitat suitability and spatial optimization models. We first developed a spatially explicit habitat suitability index (HSI) model to identify suitable nesting sites at five locations in northern Ohio. We then used the HSI output to estimate the carrying capacity at each location. We modeled carrying capacity as an anti-covering location problem, a spatial optimization model that determines the maximum number of breeding pairs an area can support, given that nests must be spaced 3000 m apart. Our results indicate that habitats in Ohio where cranes currently breed are near carrying capacity, while unoccupied suitable habitats are available in other portions of the state. This analysis enables wildlife managers to identify priority locations for crane conservation in Ohio and to determine which restoration efforts (*e.g.* habitat restoration or population augmentation) are most likely to succeed at each location. Our methodology provides an important and innovative conservation tool that can be applied to other species with strong attachment to sites (*e.g.* nest or den) that are optimally spaced at some minimum distance from conspecifics, competitors, predators, or sources of disturbance.

1. Introduction

Small local populations (12–15 pairs) of sandhill cranes were historically known to nest near Lake Erie in northwestern Ohio until 1875 (Peterjohn, 2001). These populations were extirpated by 1880, following extensive conversion of bogs and wetlands to agricultural uses. Summering birds were reported across northern Ohio until the early 1930s, but nesting was not confirmed there until 1987 (Peterjohn and Rice, 1991). Greater sandhill cranes have nested in freshwater marshes in northern Ohio annually since then (Meine and Archibald, 1996; Ohio Division of Wildlife, 2002). While sandhill crane populations throughout the Great Lakes Region have expanded dramatically during recent decades – from 8000 to 10,000 birds in 1973

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(Lewis et al., 1977) to a more recent estimate of ≥30,000 (Meine and Archibald, 1996) – Ohio's population has remained relatively small (~12 breeding pairs) (Downs, 2004). The goal is to restore a viable population of sandhill cranes in Ohio to the point where the species can be down-listed from state-endangered by 2010 (Ohio Division of Wildlife, 2000). Sandhill crane restoration plans currently under consideration include habitat enhancement, habitat restoration, and possibly population augmentation. However, it is not known if habitats in Ohio can support additional breeding pairs, and estimates of breeding pair carrying capacity are needed before restoration efforts are conducted. If all suitable habitats in Ohio have reached carrying capacity, then augmenting the population by reintroducing either captive-reared or wild cranes will not facilitate population growth without habitat enhancement or restoration. Similarly, if the population is below carrying capacity and limited by non-habitat factors that suppress recruitment, then habitat enhancement or restoration may not be effective without population augmentation. Identifying which habitats in Ohio are at or near carrying capacity will help determine which restoration efforts are most likely to be successful at particular locations.

Suitable nesting habitat must first be identified to estimate the number of sandhill crane breeding pairs that Ohio can support. Cranes in the Great Lakes Region nest in shallow marshes dominated by emergent vegetation such as sedge (*Carex* spp.) or cattail (*Typha* spp.) (Walkinshaw, 1973; Urbanek and Bookhout, 1992; Herr and Queen, 1993). Cranes prefer to nest in large marshes or in smaller wetlands located near other wetlands (Baker et al., 1995). The most important determinant of nest site suitability is the juxtaposition of the nesting marsh to food sources (Armbruster, 1987; Downs, 2004). Great Lakes cranes readily feed in row crop fields throughout the breeding season and extensively use grass or pasture during the brood-rearing phase (Bennett, 1978; Downs, 2004). Optimal crane habitat includes a large expanse of emergent marsh that is near both row crop and grass habitats. Identifying these sites is crucial to developing a successful conservation strategy for cranes in Ohio.

Habitat suitability index (HSI) models (United States Fish and Wildlife Service, 1981) are commonly used to assess habitat quality and identify potentially suitable habitat for particular species (see Roloff and Kernohan, 1999; Ray and Burgman, 2006; Van der Lee et al., 2006). HSI models incorporate life history information, such as the structure and composition of preferred habitats, into a mathematical model that indexes overall habitat quality on a scale of 0 (unsuitable) to 1 (optimal). Armbruster (1987) developed an HSI model to evaluate habitat for greater sandhill cranes in North America. Model inputs included: amount of evaluation area in wetlands (weighted by wetland class and water regime), amount in uplands (weighted by cover type), and size of disturbance-free site. However, this model was only designed to evaluate broad-scale habitat suitability for cranes and cannot be used to identify suitable locations for nesting sites.

Herr and Queen (1993) developed a GIS-based habitat suitability model to predict crane-nesting sites in northwestern Minnesota using land cover data. First, land cover types that provided suitable nesting substrate (emergent wetland and open sedge marshes) were identified as potential nesting sites. Then, the suitability of each potential site was evaluated based on distance to roads, distance to agricultural lands, and size of the disturbance-free site. This model did not accurately predict known nesting sites, although the authors noted that its poor performance was likely because spatial arrangement of habitat or other landscape characteristics were not incorporated into the model. Spatial arrangement of habitat is widely recognized as an important determinant of habitat suitability for many species (see Guisan and Zimmermann, 2000), and many more recent habitat suitability models aim to explicitly incorporate these spatial features into their formulations using geographic information systems (GIS) (*e.g.* Rickers et al., 1995; Hepinstall et al., 1996; Gurnell et al., 2002; Santos et al., 2002, 2006; Gibson et al., 2004; Store and Jokimaki, 2003; Carter et al., 2006; Dayton and Fitzgerald, 2006; Mathys et al., 2006; Lopez-Lopez et al., 2007).

Because the spatial arrangement of suitable habitats is an important factor determining nest site suitability for sandhill cranes (Armbruster, 1987; Downs, 2004), we developed a spatially explicit, GIS-based HSI model to identify potentially suitable nesting sites for cranes in Ohio. We applied the model to five study sites in Ohio where cranes currently or historically nested. We verified the model using known nest locations. Then, we used the HSI output to estimate the carrying capacity of each site. We modeled carrying capacity as an anti-covering location problem (Moon and Chaudry, 1984; Murray and Church, 1997), a spatial optimization model that determines the maximum number of breeding pairs an area can support, given restrictions on nest spacing because cranes are territorial. We compared the carrying capacity estimates to the number of pairs present at each study area in order to identify which habitats could potentially support additional breeding pairs. Finally, these results were used to formulate management recommendations for sandhill crane conservation in Ohio.

2. Methods

2.1. Study areas

This study was conducted at five habitat complexes in northern Ohio where sandhill cranes either had been confirmed breeding since the 1980s or had historically nested (Fig. 1). Cranes historically bred in the Lake Erie marsh region (Peterjohn, 2001), although they have not been documented nesting there since the early 1920s (Meine and Archibald, 1996). For this study, we considered the Lake Erie marshes (LEMA) to include the 0.25-km border of Lake Erie that extended from Cedar Point National Wildlife Refuge to the eastern edge of Sandusky Bay at Bay View. The Killbuck Marsh-Funk Bottoms (KMFB) study area was located in Wayne and Holmes Counties and remains Ohio's largest marshland complex outside the Lake Erie region. KMFB included two distinct blocks of habitat, Killbuck Marsh Wildlife Area (2200 ha) and Funk Bottoms Wildlife Area (370 ha), that were located approximately 10 km apart. Downs (2004) documented seven nesting pairs at KMFB during 2004, the largest concentration of breeding cranes in the state. La Su An Wildlife Area (LSWA) is located in Williams County in extreme northwest Ohio. LSWA