

2016

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McKinney, Lindsey F.; Barzen, Jeb A.; Riddle, Jason D.; Dubay, Shelli A.; and Ginnett, Tim F., "DIFFERENTIAL DETECTION OF TERRITORIAL AND NON-TERRITORIAL GREATER SANDHILL CRANES IN SUMMER" (2016). *Proceedings of the North American Crane Workshop*. 344.
<http://digitalcommons.unl.edu/nacwgproc/344>

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DIFFERENTIAL DETECTION OF TERRITORIAL AND NON-TERRITORIAL GREATER SANDHILL CRANES IN SUMMER

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Abstract: Abundance estimates allow wildlife managers to make informed management decisions, but differential detectability of individuals can lead to biased estimates of abundance. Our objective was to quantify detectability for non-territorial and territorial sandhill cranes (*Grus canadensis tabida*) during summer. We hypothesized that territorial sandhill cranes would be detected more often than non-territorial cranes. In 2009, 3 wetland areas were surveyed 2 days per week during the nesting season near Briggsville, Wisconsin. We created capture histories for color-marked territorial ($n = 52$) and color-marked non-territorial cranes ($n = 23$) and used the Huggins closed capture model in program MARK to estimate detection probability and abundance for each group. *A priori* models were developed that explained daily crane detection over the sampling period using distance from road, territorial status, observation event, and time of season as variables. The best approximating model included the variables territorial status and observation event (AIC_c weight = 0.92). Probability of detection was higher for territorial (0.11, 95% CI = 0.08-0.14) than for non-territorial (0.03, 95% CI = 0.01-0.07) sandhill cranes. In subsequent observation events, detection probability almost doubled to 0.18 (95% CI = 0.17-0.20) for territorial cranes, and almost tripled to 0.11 (95% CI = 0.09-0.14) for non-territorial cranes. Potential reasons for differential detection during subsequent observations include differing degrees of movement by birds and/or an observer effect in which the ability to observe birds or the perception by technicians of birds increased over time.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 13:25-32

Key words: *Grus canadensis tabida*, population size, sandhill crane, territorial status, Wisconsin.

Populations of greater sandhill cranes (*Grus canadensis tabida*) declined significantly in the early twentieth century (Henika 1936, Johnsgard 1983) but have recently recovered (Kruse et al. 2013). Currently, the eastern population (EP) of greater sandhill cranes is monitored by counts of all individual cranes seen during migration, and the raw counts are thought to serve as an index of true abundance (Kruse et al. 2010). Raw counts have been scrutinized by researchers because they do not account for changes in detection probability through time (Lancia et al. 2005, Giudice et al. 2013). Methods that attempt to account for detection probability, however, may be biased due to heterogeneous detection probabilities between individuals or groups within a species (Link 2003). A difference in movement patterns between territorial and non-territorial cranes in summer or between family groups and non-family groups in winter for example, may cause differences in detection probability which could make a population estimate

less representative of true abundance. The U.S. Fish and Wildlife Service has recognized the disadvantages of raw counts and emphasized identifying reliable means of counting and monitoring the EP of greater sandhill cranes during migration (Kruse et al. 2010) and the remnant population of whooping cranes (*Grus americana*) in winter (Butler et al. 2013).

Detection probabilities are used to calculate more precise population estimates for many wildlife species (Butler et al. 2013). Social characteristics of a population, however, might influence detection probabilities differentially. To understand the application of detection probabilities for sandhill crane populations, we examined a well-studied population where social characteristics were known and could potentially influence detection probabilities. During the breeding season, sandhill cranes separate into 2 sympatric social groups: territorial and non-territorial birds (Walkinshaw 1973, Su 2003, Hayes and Barzen 2006). Territorial cranes are adults which actively and repeatedly exclude conspecifics from a finite area (Bennett and Bennett 1992) and these cranes have consistently nested in, and defended, the same territory

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over multiple summers (Hayes and Barzen 2006, Hayes 2015). Conversely, non-territorial cranes do not defend a territory and include subadult cranes, adult cranes that are capable of breeding but do not have territories, and adult cranes incapable of breeding (Hayes and Barzen 2006).

Movements of territorial cranes also differ from non-territorial cranes during the breeding season (Su 2003, Hayes and Barzen 2006). Non-territorial cranes have larger home ranges and travel farther from roost sites each day than do territorial cranes, which must remain within a specific area to exclude other cranes (Su 2003, Hayes 2015, Miller and Barzen 2016). During the breeding season, when not incubating, territorial cranes are most often observed in pairs or families while non-territorial cranes congregate in groups that vary from single birds to many individuals, sometimes exceeding 100 individuals (Miller 2002, Su 2003). The difference in movement and grouping patterns between these 2 social groups may affect detection rates and consequently affect abundance estimates from survey data.

Quantifying detection probabilities for each social group may help improve estimates for both population abundance and relative abundance of territorial and non-territorial groups. Relative abundance of these groups is meaningful because individuals within each group do not provide the same reproductive contribution to the population (Mills 2007). If part of the crane population is not able to contribute to recruitment due to lack of a nesting territory within suitable habitat, population dynamics and the population's response to pressure due to the hunting of cranes can be affected (Watson and Jenkins 1968, Mills 2007). Population fluctuations may be more affected by the amount of suitable habitat than by the number of adult cranes in the population (Watson and Jenkins 1968, Lande 1987, Fryxell 2001). Ecologically, the relative size of each social group also may influence social dynamics between groups (Nesbitt and Wenner 1987, Nesbitt et al. 2001, Hayes 2015).

Our objective was to estimate detection probabilities for 2 social groups of sandhill cranes, territorial and non-territorial, as a part of a larger effort to quantify the abundance of both social groups on a breeding area in Briggsville, Wisconsin. We are aware of only 1 other published estimate of detection probability for a crane species. Strobel and Butler (2014) estimated detection probability (± 1 SE) of 0.558 ± 0.031 within 500 m of aerial transects for whooping cranes. We hypothesized that territorial and non-territorial cranes would have

different probabilities of detection because of different movement patterns (Su 2003, Hayes 2015, Miller and Barzen 2016). We also evaluated the effect of site size, distance to road, time of season, and observer bias on detection of cranes.

METHODS

Study Area

The study area was located near Briggsville, Wisconsin ($43^{\circ}36'N$, $89^{\circ}36'W$), in an unincorporated township at the junction of Adams, Columbia, and Marquette counties, Wisconsin. The 6,600-ha site included 3 large wetland areas (100-200 ha) that were dominated by wetland species of sedge (predominantly *Carex* spp.). These wetlands maintained relatively constant water levels through groundwater inflow while wetland discharge was primarily from channelized outflow through streams that bisected each wetland (Barzen et al. 2016). In addition to larger wetlands, numerous smaller wetlands (<10 ha) were also present (Su 2003) and tended to be perched wetlands (Mitsch and Gosselink 2000). Wetland areas were surrounded by agricultural fields composed mainly of corn, alfalfa, and soybeans. Residential homes, grasslands, and forest were the other predominant types of land use in our study area (Su 2003).

Survey Methods

Sandhill cranes used in our analysis were previously color-marked (prior to 2009) by the International Crane Foundation. Cranes were captured as flightless chicks by chasing chicks until they hid (Hoffman 1985) or by baiting family groups after chicks could fly using corn treated with the sedative alpha-chloralose (Hayes et al. 2003, Hartup et al. 2014). Non-territorial cranes were color-marked when they were chicks in family groups during 2008 or before and then observed in 2009 as non-territorial cranes. Territorial sandhill cranes were either captured as territorial adults in 2008 or earlier or as chicks in a family group before 2008 and becoming territorial by 2009. Once restrained, a Bird Banding Laboratory (U.S. Geological Survey) metal leg band, a 7.62-cm plastic leg band displaying a unique, field-visible number, and 3 colored, 2.54-cm plastic leg bands indicating a unique identification code were attached (Dickerson and Hayes 2014).

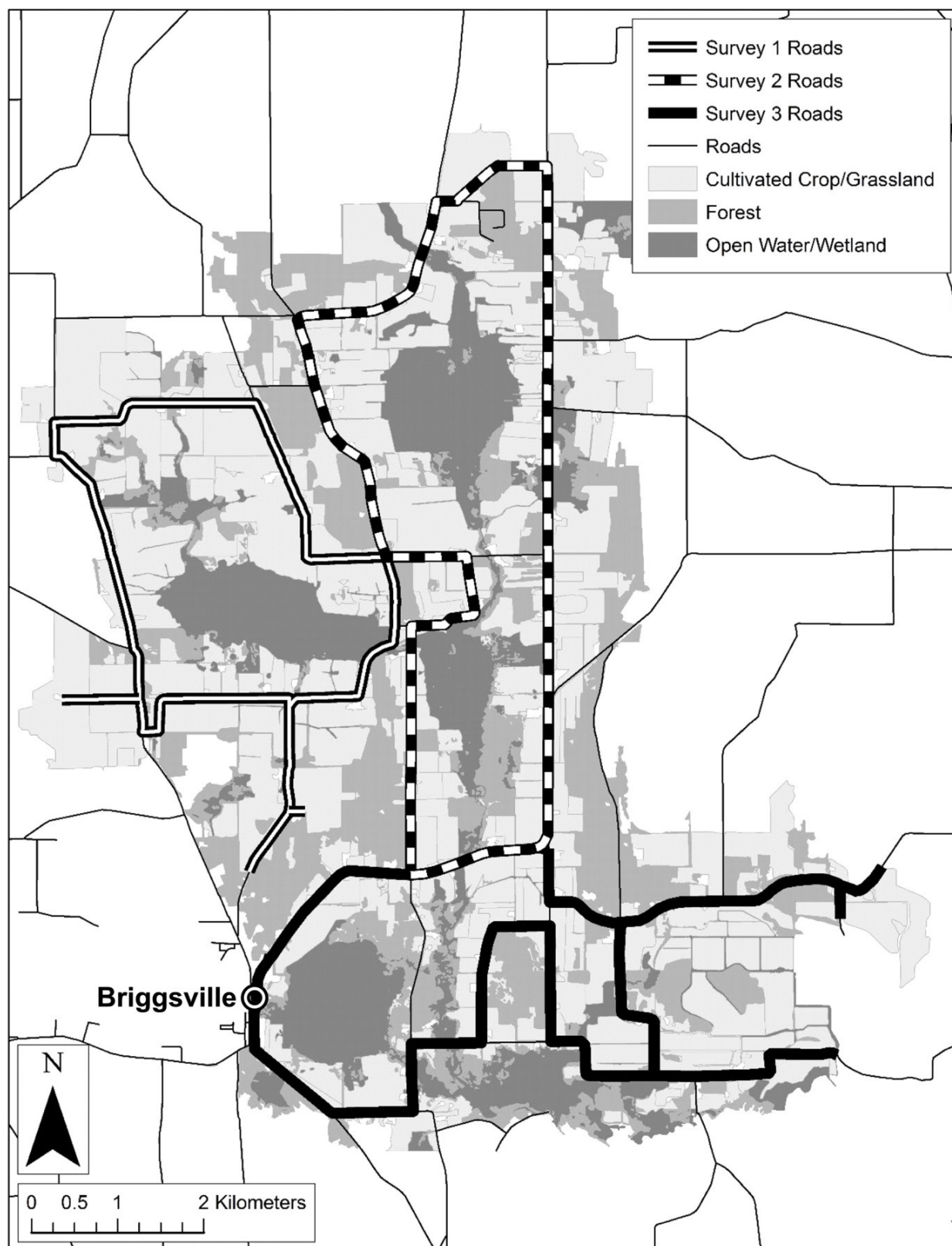


Figure 1. Three survey routes for sandhill crane observation from vehicles, near Briggsville, Wisconsin, 2009. Gray habitats were visible during the survey while white areas were not.

Sandhill cranes return to the Briggsville area to breed between late February and early March (Hayes and Barzen 2006). Surveys began on 3 April 2009 and ended on 16 June 2009. Each survey consisted of 3 routes (17.9 km, 21.8 km, and 24.5 km) on public roads, with each route circling 1 of the 3 primary wetland areas (Figure 1). Four technicians participated in observations during the field season. Technicians observed cranes on both sides of the road when vegetation or houses did not obstruct their view. Vegetation emergence and growth throughout the study did not affect the field of view. Each survey took approximately 1 hour to complete and circumnavigated 1 wetland complex. One survey day consisted of a technician driving the specified survey route 6 times during time periods that were stratified from a half hour before sunrise to a half hour after sunset. Each survey began at 1 of 6 randomly chosen starting points. In our analysis a “survey day” refers to all 6 surveys in 1 day and a “survey” will refer to 1 survey on any given day. Technicians observed cranes from a vehicle using binoculars (10×42) and spotting scopes (20–60× zoom), and recorded the color combinations of bands along with the locations of all banded cranes on printed aerial photos of the survey area. Technicians performed surveys twice a week at each wetland or route for a total of 67 survey days over 55 days of sampling (1 route was surveyed 1 extra time).

Data Analysis

We used the Huggins closed capture model (Huggins 1989) in Program MARK (version 7.1, White

and Burnham 1999) to explore differences in detection probabilities across the 2 social groups of sandhill cranes for color-marked birds only. The Huggins model also allowed us to model the effect of covariates on detection (Huggins 1989). Capture histories were created for each banded crane by treating each day as an observation event and pooling all 6 runs of a survey route. Thus, if a crane was sighted during any of the 6 runs in a day, it was coded as a 1, and if it was not seen at all it was coded as a 0. Only color-marked sandhill cranes that were confidently identified were included in our analysis. Only 5% of observed, color-marked birds were excluded.

Territorial cranes were identified as a pair of cranes occupying the same breeding and foraging area daily and displaying territorial behavior, such as low bows or ruffle bows directed at a conspecific near consistent boundaries (Tacha 1988), or nesting behavior such as incubation, nest building or nest exchange. Further, cranes were considered territorial in 2009 if they were classified as territorial during the 2008 breeding season and returned in the 2009 season paired with the same individual on the same territory location. We used this criterion so that territorial status could be used early in the season at the beginning of observations (3 April). Territoriality otherwise would take days to weeks to determine because the definition requires a series of observations. We identified the territorial status of all banded cranes and used this as a covariate in our analysis (Territorial status, Table 1). Non-territorial cranes neither defended a consistent area nor displayed repeated aggressive behavior toward conspecifics at a

Table 1. Detection models fit to sandhill observation data from 67 surveys along 3 routes, Briggsville, Wisconsin, 3 April–16 June 2009.

Model	K ^a	AIC _c ^b	ΔAIC _c ^c	AICc weight ^d	Model likelihood
Territorial status + observation event	4	3358.7	0	0.92	1
Time of Season + territorial status + observation event	12	3363.7	4.97	0.08	0.0831
Time of season + observation event	6	3388.0	29.33	0	0
Observation event	2	3390.9	32.18	0	0
Territorial status	2	3394.2	35.49	0	0
Time of season + territorial status	6	3397.9	39.26	0	0
Distance	2	3428.5	69.80	0	0
Null	1	3441.3	82.59	0	0
Time of season	3	3441.6	82.95	0	0

^a Number of parameters.

^b Akaike's Information Criterion corrected for small sample size.

^c Difference in AIC_c relative to minimum AIC_c.

^d Akaike weight.

specific location, and were most likely found in groups of 3 or more (Su 2003). We used observation histories of banded individuals to separate observations into first observation and subsequent observations, meaning any observation after the first observation (Observation event). This separation tested for the effect of independence for abundance estimates, which has been documented in other studies (Riddle et al. 2010). We would expect that if detection probabilities during initial and subsequent observations were independent and unbiased the probability of detection would not increase after the initial observation. At least 2 outcomes would explain a rejection of this hypothesis for independence: First if an observer learned to better identify cranes after an initial observation (this would be analogous to a trap response in traditional mark-recapture models), there would be an increase in detection probability after the first sighting. Second, if crane movements were non-random we would also expect detection probabilities between first and subsequent observations to be different.

We used ArcGIS software (Environmental Systems Research Institute, Inc., Redlands, CA) to determine the distance from the survey road to an observed crane for each sighting. The average distance of the crane from survey road over the entire 55 days of data collection was used in the analysis (Distance). We split observations into 3 intervals, each spanning 18-19 survey days to test the effect of time of season on detection probability (Time of season). This corresponded to the dates 3-25 April, 26 April-22 May, and 24 May-16 June.

Finally, we tested 9 *a priori* models containing 4 covariates (Territorial status, Observation event, Distance, and Time of Season) because we hypothesized that each covariate could affect detection probability. We also tested a null model. Akaike's Information Criterion (AIC; Burnham and Anderson 2002) was used for model selection. Due to the relatively small sample size of cranes in conjunction with variables (K) in several models (i.e., $n/K < 40$), we used AIC corrected for small sample size (AIC_c) for model selection (Burnham and Anderson 2002). We drew primary inference from models within 2 units of AIC_{min} , although models within 4-7 units may have limited empirical support (Burnham and Anderson 2002).

RESULTS

In 2009 we observed 52 uniquely banded territorial sandhill cranes and 23 uniquely banded non-territorial

sandhill cranes. The model including territorial status + observation event best explained detection probability for sandhill cranes and had an Akaike weight of 0.92 (Table 1). The second best model included territorial status, observation event, and time of season. This model, however, was $4.97 \Delta AIC_c$ units from the first, providing little model support (Burnham and Anderson 2002). All other models were noncompetitive.

We calculated detection probabilities for both social groups of cranes as well as for first and subsequent observation events within the social group. The detection probability (± 1 SE) upon first observation for territorial sandhill cranes ($= 0.11 \pm 0.01$, 95% CI: 0.08-0.14) was 3 times greater than for non-territorial sandhill cranes ($= 0.03 \pm 0.01$, 95% CI: 0.01-0.07). In addition, detection probabilities for both social groups increased after the initial observation. Territorial sandhill cranes were 1.5 times more likely to be detected after an initial observation ($= 0.1 \pm 0.018$, 95% CI: 0.17-0.20), and non-territorial cranes were more than 3 times more likely to be detected after an initial sighting ($= 0.11 \pm 0.01$, 95% CI: 0.09-0.14).

For territorial sandhill cranes the population estimate (± 1 SE) derived from the best model was 52.1 ± 0.35 individuals (95% CI: 52.0-54.3) and for non-territorial cranes, it was 27.5 ± 4.8 individuals (95% CI: 23.8-47.9).

DISCUSSION

Although detection probabilities of cranes per day were low, the number of surveys conducted was sufficient to detect $\geq 99\%$ of territorial cranes and 85% of non-territorial cranes. Of the models we prepared *a priori*, overwhelming support for the models containing territorial status suggested that territorial and non-territorial cranes are detected at different rates on the breeding grounds. Using either initial observations or subsequent observations, territorial cranes were more likely to be detected on any given day than non-territorial cranes. We speculated that the greater detection rate for territorial cranes was because of their restricted movement patterns on the breeding grounds as compared to the broader home ranges of non-territorial cranes. Home range size for territorial sandhill cranes in the Briggsville area varied over the breeding season with a mean of 284.7 ± 59.7 ha ($n = 12$, Miller and Barzen 2016). In the same population, home range sizes for non-territorial cranes decreased with age

but were still over 22 times larger than territorial home ranges (Hayes and Barzen 2016). Restricted movement of territorial cranes may cause them to be present more often within the survey area and more available for observation.

The use of individual observation histories in the Huggins model revealed that detection probabilities for both social groups increased between initial and subsequent observation events. The Huggins closed capture model identified both territorial status and observation event as contributing to detection probability. Territorial cranes were 1.5 times more likely to be observed after the initial sighting, and non-territorial cranes were more than 3 times more likely to be observed after the initial sighting. Aspects of sandhill crane or observer behavior (or both combined) could account for an increase in detection probability after an initial observation. For instance, observers may learn where to look for sandhill cranes over time, or sandhill cranes may begin to use the same fields over time to improve social interaction or foraging efficiency. The effect of observer bias on abundance estimates has been documented in other studies (Riddle et al. 2010). Even when following standard methods for surveys, unforeseen biases in detection can affect survey results (Giudice et al. 2013). Environmental variables and heterogeneity between individuals being surveyed have been identified as important variables to consider when conducting detection probability studies (Conn et al. 2006, Giudice et al. 2013). Non-random sandhill crane behavior, as an example of individual heterogeneity, can also be important. With home ranges of non-territorial cranes covering 28-197 km² (Hayes and Barzen 2016), environmental conditions that modify habitat use can quickly skew sandhill crane behavior to increase repeated observations in a small area when resources such as food, for example, become available that can attract foraging cranes. Our survey applied many conventional methods designed to decrease survey bias, such as random starting points and observer training, but our results still show linkage between initial and subsequent observation events, so detection bias was possible. We also recognize that factors not identified by our analysis may affect detection probability of sandhill cranes.

Managers should take detection probability into consideration when deciding on survey methods to monitor sandhill crane species (Conway and Simon 2003). Our study found that territorial sandhill cranes

during the breeding season had a substantially higher detection probability than did non-territorial sandhill cranes. Fewer surveys, therefore, may be needed to estimate population sizes for territorial than for non-territorial sandhill cranes. Spring census techniques that use volunteers to record unison-calling cranes (Voss 1977), illustrate examples of survey techniques (Harris and Knoop 1987, Dietzman and Swengel 1994) that may effectively detect territorial versus non-territorial cranes and can benefit from these results. Accurate census of most sandhill crane populations is difficult, so survey methods that incorporate detection probability estimates are valuable to wildlife managers who wish to monitor these cranes. Currently, an index of the EP of sandhill cranes is taken during fall migration (Kruse et al. 2010).

ACKNOWLEDGMENTS

We thank A. Gossens, J. Oesper, J. Arntzen, and M. Durkin for collecting survey data. A. Gossens created Figure 1; J. Langenberg and 2 anonymous reviewers provided helpful comments that improved this paper.

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