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Abstract: Captive-bred Mississippi sandhill cranes (*Grus canadensis pulla*) suffer from low recruitment in nature, and poor nest defense ability may significantly contribute to the problem. We hypothesized that a lack of opportunities for social learning by young birds prior to release inhibits the development of appropriate nest defense in later life. Here we report the results of preliminary experiments on conditioning of antipredator behavior in young birds prior to release using predator models. Observing agonistic displays by either costumed technicians or parent birds toward a model raccoon (*Procyon lotor*) promoted aggressive displays to a wild raccoon, but additional exposure to wild raccoons outside of training sessions instead promoted habituation. Pre-release conditioning of crane chicks can induce antipredator behavior useful in nest defense, but optimal procedures remain to be determined.

The use of captive-bred animals to supplement wild populations under threat or to reintroduce extirpated species into their previously occupied range has become a common tool in conservation biology (Kleiman 1989; Price 1999; Seddon et al. 2007, 2014). However, it has become clear that captive-bred animals often lack behavioral skills required for survival and successful reproduction after release (Kleiman 1989, Miller et al. 1994, Curio 1998, Griffin et al. 2000, Bell 2016). The captive-rearing environment lacks the complexity of natural environments (Yoerg and Shier 1997) and may provide only limited opportunities for learning skills by observing other individuals (Griffin et al. 2000, Griffin 2004). Captive-reared animals may not be able to observe parents or other conspecifics exhibit the full range of behaviors required for successful reintroduction and may at times be reared in isolation from other conspecifics. Providing opportunities to learn appropriate antipredator, social, foraging, and habitat selection behaviors during rearing may greatly enhance the probability of successful reintroduction of captive-bred animals (Shier 2016).

The Mississippi sandhill crane (*Grus canadensis pulla)* has been the focus of a long-term reintroduction program since 1981 (Ellis et al. 2000) but has not yet achieved a reproductive rate sufficient to sustain the wild population without continued supplementation (Hereford and Dedrickson 2016). Predator pressure appears to be a major contributor to poor reproduction on the Mississippi Sandhill Crane National Wildlife Refuge (MSCNWR) (Butler 2009), and a recent study documented a widespread lack of nest predator recognition and antipredator behavior among captive-reared birds released on the refuge (Howard et al. 2016). Many of the birds that showed deficits in predator recognition and nest defense were costume-reared prior to release, and we hypothesize that a lack of social learning during development (Heyes 1994) may contribute to poor nest defense skills and low fledging success.

Here we report the results of pilot studies aimed at training captive-reared crane chicks to recognize nest predators and learn nest defense behaviors through social learning. Social learning is common among birds (Griffin 2004), is required for predator recognition and avoidance in many taxa (Curio 1988, Griffin and Evans 2003, Griffin 2004, Shier and Owings 2007), and is known to be associated with the acquisition of migratory behavior in whooping cranes (*Grus americana*) (Mueller et al. 2013). In the absence of exposure to conspecifics, aversive training involving exposure to natural predators (Maloney and McLean 1995), live predator substitutes (Ellis et al. 1977, McLean et al. 2000), and inanimate predator models (Miller et al. 1990; McLean et al. 1996, 1999) has been effective in

promoting the ability of threatened species to recognize and avoid predators. However, these studies emphasized predator avoidance rather than defense, which is likely to require observation of agonistic behavior in a specific context rather than generalized aversion training. In a previous study (Heatley 2002), sandhill crane chicks were able to observe experienced adult cranes react to live, tame predators, either a bobcat (*Lynx rufus*) or a coyote (*Canis latrans*). Observation of adult cranes that displayed antipredator behavior when presented with predators significantly increased the frequency of alert behaviors in chicks compared to chicks that were not allowed to observe adults. However, observation of adult cranes did not promote agonistic displays necessary for nest defense, perhaps because adult cranes in this study mostly displayed avoidance rather than agonistic behaviors (Heatley 2002). In this study we chose to use inanimate predator models and to explicitly model nest defense behaviors known to be effective against common nest predators at MSCNWR (Howard et al. 2016).

Costume-rearing of cranes for release at MSCNWR began in 1989 at the Patuxent Wildlife Research Center in Laurel, Maryland (Ellis et al. 1992), by using methods adapted from Horwich (1989). Currently, costume-reared cranes are produced from captive flocks at the Freeport-McMoRan Audubon Species Survival Center (SSC) in New Orleans, Louisiana, while parent-reared cranes are produced at both SSC and White Oak Conservation Center in Yulee, Florida. In costume-rearing at SSC, crane chicks are raised by technicians wearing cotton costumes and face screens to prevent imprinting on humans (Ellis et al. 1992). Hand-held model crane head puppets are used to guide chicks in feeding and drinking, and chicks are able to observe adults in adjacent pens from the day of hatching. One modification of the Patuxent protocol is that costumed caretakers do not perform any tasks (e.g., cleaning cages) that cranes would not normally do; such tasks are instead carried out while wearing ghillie (camouflage) suits. In parent-rearing, chicks are raised by either natural or foster parents in large enclosures mimicking natural conditions as closely as possible. However, in both cases the captive-rearing environment provides only limited opportunities for chicks to learn the full range of behaviors required to respond to challenges they may encounter upon release.

The study was conducted on 4 costume-reared and 1 parent-reared crane chicks at the SSC in New Orleans, Louisiana. Costume-reared chicks at SSC were individually housed in a building connected to an exercise and foraging pen surrounded by chain link fencing with a visual barrier of black cloth netting 1-m high to prevent contact between cranes and animals outside the enclosure. Pens for costume-reared chicks were 12 × 12 × 2.2 m and roofed with 2.5-cm flight netting. Parent-reared chicks were housed with parental pairs in fenced pens 12 × 28 × 2.2 m with visual barriers at the base and topped with flight netting as described above. At 60-90 days of age, chicks were placed together in groups for socialization and housed in 2-3 linked pens 12 × 28 × 2.2 m to allow them to move freely through a larger area. Socialization pens were surrounded by an electrified wire to prevent potential predators from approaching.

We conditioned 2 costume-reared chicks in 2015 (MSC ID nos. 1501 and 1502) and 2 in 2016 (MSC ID nos. 1602 and 1604), using a life-size plush raccoon (Hansa Toys, Sunrise, FL, USA) as a model predator. In 2015, we also presented the model to a pair of crane parents and their chick (MSC ID no. 1505) to observe the reactions of the parents and contrast the reactions of chicks. Although the parents were both captive-reared, the male parent has repeatedly been observed to be aggressive toward raccoons. We selected a raccoon as the model for this experiment because they are common pests around and occasionally in rearing pens at SSC and are serious nest predators at MSCNWR (Butler 2009).

We mounted the model raccoon on a remote-controlled toy truck (Rock Crawler by Maisto International, Fontana, CA, USA; Fig. 1) in 2015 or attached it to a pulley system in 2016. To avoid habituation to the model or learning extraneous stimuli (artificial movement patterns, motor noise), we conducted only 2 training sessions separated by a month each, beginning when chicks were 3-4 weeks old. Each session was held on clear, sunny days in early afternoon to ensure that chicks could clearly see both the characteristics of the predator model and the antipredator behaviors exhibited in response. In each session the model was introduced into the rearing pen by an operator working from concealment in an access shed connected to the pen. A costumed technician responded by rushing at it giving a droop-wing threat display (pre-attack display described by Ellis et al. 1998) using wings salvaged from a dead bird, and pecking with the crane head puppet while

Figure 1. Life-size model raccoon (standing raccoon, model #5181, Hansa Toys, <https://hansatoystore.com>) mounted on a remote-controlled toy vehicle (Maisto Rock Crawler radio-controlled car). The mounted model raccoon was used to train costume-reared and parent-reared Mississippi sandhill crane chicks at the Freeport-McMoRan Species Survival Center, New Orleans, Louisiana, prior to release after fledging on the Mississippi Sandhill Crane National Wildlife Refuge.

playing recorded alarm calls. The attack continued for 1-2 minutes and was broken off when the model "retreated" by being driven or pulled back into the shed with the operator. We directly observed the reactions of chicks to the behaviors of the costumed technician or parents toward the model and monitored

subsequent behavior until chicks were fledged and ready for release at MSCNWR by using continuously recording, high-definition, infrared wildlife cameras (Bushnell, Overland Park, KS, USA) mounted in pens. After training sessions were complete, costume- and parent-reared chicks were moved to socialization pens before being transferred to MSCNWR.

During all initial training sessions, chicks retreated to the far end of their rearing enclosure and were highly attentive to the behavior of the costumed technician or parents. When the model was presented to the parental pair, the adult male persistently attacked and displayed to the model in similar fashion to the costumed technician while the adult female closely guarded the chick at a distance. In no case did chicks display agonistic behavior during training trials.

In 2015, chicks were presented with the model predator a third time after they were transferred to socialization pens in August to determine if they maintained avoidance behavior or displayed aggression toward the model as a group. Both costume- and parent-reared chicks displayed avoidance to the model in this third trial but subsequently displayed the droop-wing threat to a real raccoon (Fig. 2).

In 2016, the socialization pen underwent renovation and chicks were housed in a 12 × 28-m rearing pen for socialization. This pen lacked an electrified perimeter wire, and wildlife cameras recorded frequent exposure of costume-reared chicks to wild raccoons outside

Figure 2. Droop-wing threats given toward a wild raccoon in the 2015 pre-release pen occupied by 2 costume-reared and 1 parent-reared crane at Freeport-McMoRan Species Survival Center, New Orleans, Louisiana. Left: raccoon in proximity to a pre-fledge crane. Right: droop-wing threats given by 2 cranes; at least 1 crane was costume-reared and technician-trained. Images from Bushnell infrared game camera.

of training sessions. As a result, chicks apparently habituated to the presence of raccoons and failed to display avoidance or aggression when they were encountered adjacent to pre-release pens. Because of the apparent tolerance of raccoons by chicks, a third trial was not conducted in 2016.

Our results suggest that Mississippi sandhill crane chicks can learn to express antipredator displays from both parents and costumed technicians, and can generalize from inanimate models to real predators. This may offer crane breeding programs the opportunity to teach critical skills even in the absence of live predators or adult cranes to model behaviors. However, our results clearly demonstrate that exposure to predators must be controlled, and that reinforcement of agonistic behavior through repeated observation of conspecifics may be necessary for the maintenance of learned defense behaviors. It is likely that wild-reared cranes initially learn defensive behavior from parents, and that the behavior is maintained after separation from the parents by repeated observation of aggression toward predators by other conspecifics. The need to reinforce learned defensive behaviors during the 3-5 year pre-nesting period may prove to be a more significant barrier to teaching effective nest defense than the initial acquisition of the behavior.

While initial results appear to be promising, many questions remain to be resolved before this method can be recommended as a general training system for captive-reared cranes. The optimal number and timing of training sessions, and the importance of reinforcement remain to be determined. It is also unclear whether cranes that learn defensive behavior toward 1 model predator will be able to generalize to other mammalian mesopredators. Although some species are capable of generalization from training on 1 mesopredator to others (Griffin et al. 2003), this is not always the case (Griffin and Evans 2003). In addition to raccoons, nesting Mississippi sandhill cranes face threats from mesopredators such as coyotes, red foxes (*Vulpes vulpes*), bobcats, domestic dogs, red-tailed hawks (*Buteo jamaicensis*), American alligators (*Alligator mississipiensis*), and several snake species. The diversity of form and behavior among predators may require a comparable diversity of training models, and the ability to generalize from 1 training model to others will have important consequences for the feasibility and cost of antipredator training programs.

Another important issue is whether there exists a critical or sensitive period during which initial learning must occur. Untrained, costume-reared sandhill cranes have become effective nest defenders after release on MSCNWR (Howard et al. 2016), suggesting that birds can acquire defensive skills even if unable to observe such behaviors during early development, but it is not known whether all cranes can do so or when this learning might have occurred. It may be beneficial to provide additional training during acclimation at MSCNWR, and testing antipredator responses at this stage may prove useful in predicting the survival and breeding potential of birds. We intend to address these issues in future studies, but we caution that the long-term value of antipredator training can only be assessed by monitoring post-release survival and nesting success over the next several years.

ACKNOWLEDGMENTS

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