

Short Communication

Eradication of African sacred ibis (*Threskiornis aethiopicus*) from South Florida, USA: a collaborative early detection and rapid response case studyBryan M. Kluever^{1,*}, Michael L. Avery¹, Dale E. Gawlik², Parker Hall³, John S. Humphrey¹, Tony Pernas⁴ and Frank Ridgley⁵¹U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services, National Wildlife Research Center, Florida Field Station, 2820 East University Avenue, Gainesville, FL 32641, USA²Harte Research Institute for Gulf of Mexico Studies, Texas A&M University Corpus Christi, 6300 Drive, Corpus Christi, TX 78412, USA³U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services, Florida State Program, 2820 East University Avenue, Gainesville, FL 32641, USA⁴US Department of Interior, National Park Service, Big Cypress National Preserve, 33100 Tamiami Trail East, Ochopee, Florida, 34141, USA⁵Zoo Miami, Conservation and Research Department, 12400 SW 152nd St. Miami, FL 33177, USA

*Corresponding author

E-mail: bryan.kluever@usda.gov

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Received: 17 October 2022**Accepted:** 16 December 2022**Published:** 13 February 2023**Handling editor:** Frank Koch**Thematic editor:** Catherine Jarnevich**Copyright:** © Kluever et al.This is an open access article distributed under terms of the Creative Commons Attribution License ([Attribution 4.0 International - CC BY 4.0](https://creativecommons.org/licenses/by/4.0/)).**OPEN ACCESS****Abstract**

Successful control or eradication programs involving invasive terrestrial vertebrate species are rare, typically occurring in insular environments. The African Sacred Ibis (*Threskiornis aethiopicus*) has become established as an invasive species in several countries, causing damage to natural resources. Researchers had forecast the potential for this species to thrive in southern Florida, USA, but also noted that it was early enough in the invasion process to make eradication feasible. In 2008, State, Federal, and private entities collaborated to develop and carry out a program to eliminate African Sacred Ibis from South Florida. The program utilized the “scout” technique and an invasive species reporting and outreach platform to discover previously unidentified African Sacred Ibis use areas. Thirty-three African Sacred Ibis were captured alive, surgically pinioned, and placed at several accredited zoological parks. An additional 45 were humanely removed across five sites, which included both private and public lands. The operation was successful and at the end of the eradication there were no known free African Sacred Ibises in Florida. The potential for establishment of new African Sacred Ibis founder populations is high, and our reporting of this successful control program can aid in the success of other invasive species managers of African Sacred Ibis and other invasive large-bodied waterbirds.

Key words: early detection rapid response, invasive species, scout technique, waterbird

Introduction

The establishment of invasive species is a primary driver of biodiversity and habitat loss (Vila et al. 2011). In addition, invasive species can cause property damage, impact agriculture, and threaten human health and safety (Pitt et al. 2018). For example, feral swine (*Sus scrofa*) establishment in North America represents a species invasion that significantly impacts all of the above categories (Vercauteren et al. 2020). Eradication efforts can be challenging and are often unsuccessful (Pluess et al. 2012). Unsuccessful

eradication campaigns commonly transition to intensive long-term management efforts intended to reduce impacts, limit spread, or depress population size (Parkes and Panetta 2009; Pluess et al. 2012).

The majority of successful eradications of terrestrial vertebrate species have occurred on islands and include eradications of mammals, plants, invertebrates, and birds (Parkes and Panetta 2009). This is primarily attributed to emigration/dispersal being limited or prohibitive due to the insular environment (i.e., a closed population; Glen et al. 2013; Russell et al. 2017). Unfortunately, the methods and approaches leveraged in insular environment eradication campaigns are not always effective and/or feasible against continental invasive species populations (Parkes and Panetta 2009). Thus, chronicling and disseminating the methods and tactics employed that lead (or do not lead) to successful continental vertebrate species eradication is imperative for propagating knowledge and instruction to natural resource and wildlife managers. Though, in general, receiving less attention than invasive terrestrial mammalian (Pitt et al. 2018) and reptilian species (Engeman et al. 2011), the establishment of invasive avian species are increasing and can cause appreciable damage and human-wildlife conflict (Downs and Hart 2020). For example, accumulated global damage cost of the genus *Sturnus* (starlings) alone based on a dynamical modeling approach was estimated to be approximately US\$ 2.5 billion (Ahmed et al. 2022).

A key component toward the successful eradication of an invasive species is to identify the population at the founder stage (Parkes and Panetta 2009; Avery and Feare 2020). This is especially important for avian species as their potential rate of spatial expansion generally exceeds that of mammals and plants (van den Bosch et al. 1992). Successful non-insular eradications for avian species are rare (Downs and Hart 2020) and include the American Black Duck (*Anas rupripes*) in British Columbia (Fenneman 2011) and the African Sacred Ibis (*Threskiornis aethiopicus*) in Barcelona (Clergeau and Yèsou 2006) and south Florida, USA (Yèsou et al. 2017) [see Avery and Feare (2020) for a complete list of eradications of founder populations].

The benefits conferred from successfully eradicating African Sacred Ibis populations are difficult to quantify, but are potentially substantial for several reasons. Firstly, African Sacred Ibis prey upon active nests and/or chicks of a variety of avian species (Maillard et al. 2020). In France, African Sacred Ibis preyed on the eggs and chicks of various species of gulls, terns, and egrets (Yèsou et al. 2017). Such predation can be opportunistic or consist of deliberate and systematic searching (Maillard et al. 2020). Secondly, invasive populations of African Sacred Ibis can carry historically documented and novel strains of avian chlamydiosis, which have the potential to be spread to native avian species, humans, and domestic birds (Vorimore et al. 2013). In addition, as a large-bodied species, the African Sacred Ibis poses a potential collision risk to aircraft, with collisions reported in several African countries (Viljoen and Bouwman 2016). Finally, founder

populations of only a few dozen individuals can grow into large populations. For example, in Italy, the population increased from a few dozen to nearly 11,000 individuals over 30 years (Cucco et al. 2021) and in Taiwan the population reached 10,000 after approximately three decades of birds escaping from captivity (Ku et al. 2023).

As they are relatively easily maintained in captivity, African Sacred Ibises are held by many zoological parks around the world and also by private citizens due to cultural/religious significance or for private menageries (Curtis et al. 2018). A number of escapes and releases have taken place, and the probability of future escapes and releases is high (Yèsou et al. 2017; Maillard et al. 2020). Stochastic events, such as hurricanes or tornadoes, present the potential for introductions of this species to compatible environments in North America. Currently, invasive breeding populations of African Sacred Ibis occur in France, Italy, Taiwan, and the United Arab Emirates, with nonbreeding populations occurring in several additional European countries (Maillard et al. 2020). The behavioral and dietary flexibility of the African Sacred Ibis allows for the potential of breeding populations establishing throughout many parts of the globe (Maillard et al. 2020).

Although being recognized as a successful eradication effort (Yèsou et al. 2017; Avery and Feare 2020), little has been reported on the approaches employed to eradicate African Sacred Ibis from south Florida. Here, we provide a detailed account of this rare example of a non-insular avian species eradication.

Materials and methods

Study site

Our study area comprised Monroe, Collier, Broward, Miami-Dade, and Palm Beach Counties, Florida, USA (Figure 1). This corresponds principally with the Everglades Cooperative Invasive Species Management Area (ECISMA). The ECISMA is a partnership of federal, state, and local government agencies, universities, tribes, and nonprofit organizations that manages, researches, and educates about invasive species across South Florida, encompassing the southern Florida Coastal Plain Ecological Region (Level III, Omernik and Griffith 2014) and the Florida Everglades, the largest wetland in the United States (Lodge 2017). This matrix of urban, wetland, and agricultural land cover represents highly suitable habitat for the African Sacred Ibis (Omernik and Griffith 2014), a species with high human commensalism. For example, the African Sacred Ibis observed breeding in the Florida Everglades averaged only 7.5 km away from human developments, and were located in some of the closest wading bird colonies to developed areas (Herring and Gawlick 2008).

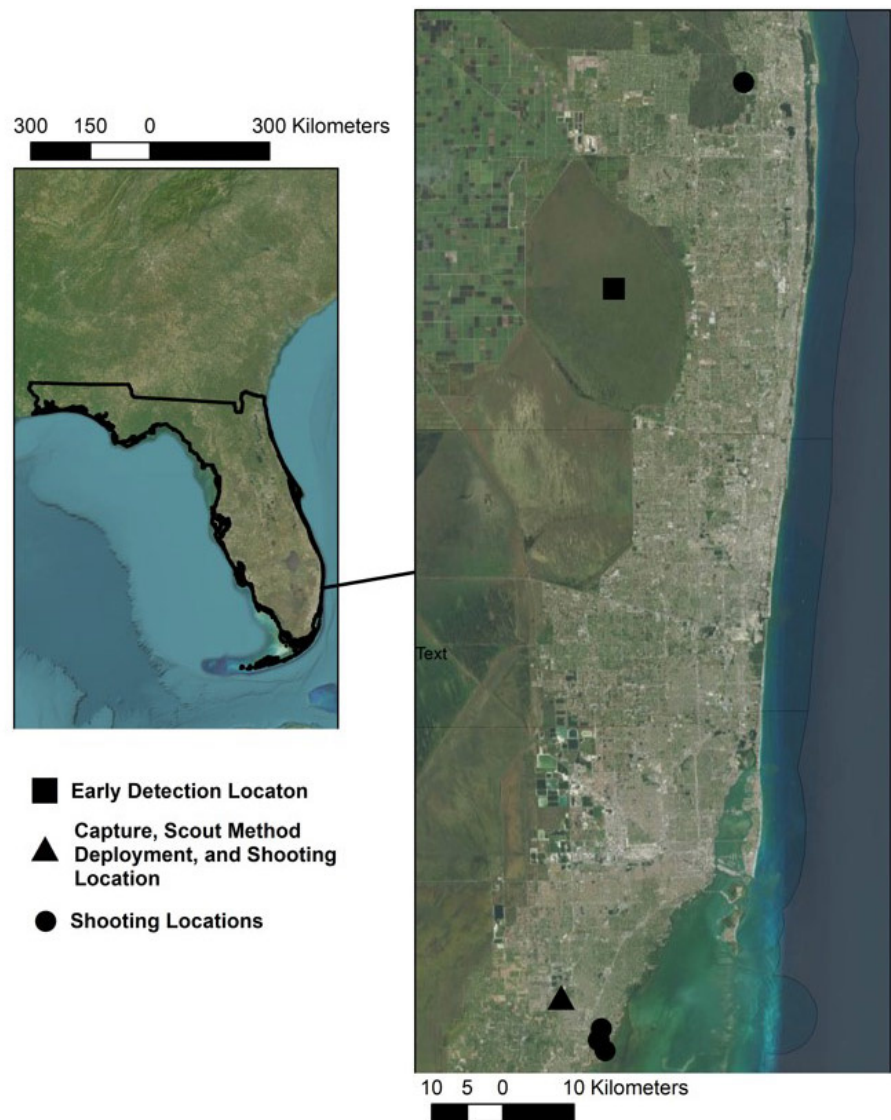


Figure 1. Map of Florida (left) and southeastern Florida (right) where a successful eradication of African Sacred Ibis (*Threskiornis aethiopicus*) took place in 2008. Early detection at the Loxahatchee National Wildlife Refuge by a University researcher prompted a concerted effort to capture birds and employ the scout technique on two transmitter affixed birds. The scout method and reported species sightings resulted in identifying additional roost locations (4) where shooting operations took place.

An unknown number of African Sacred Ibis escaped from various captive animal facilities in south Florida following the destruction caused by Hurricane Andrew in 1992 (Herring et al. 2006). Sporadic sightings of the species were restricted to urban areas until 2005 when breeding birds were detected by researchers in wading bird (Ciconiiformes and Pelecaniformes) colonies in the Arthur R. Marshall Loxahatchee National Wildlife Refuge, and other parts of the Everglades (Herring et al. 2006). The recognition that this species had expanded out of urban habitat into a wetland of global significance, where it could become an additional stressor, prompted a rapid evaluation of the risk of establishment (Herring and Gawlik 2008). In 2007, multiple birds were observed foraging at Zoo Miami (at the time known as the Miami Metrozoo). In 2008, the ECISMA

members recognized the risks of this species' expansion in Florida, and its still limited distribution. An Early Detection Rapid Response (EDRR) strategy (Reaser et al. 2020) was developed to remove wild, free-flying African Sacred Ibis to contain the population, and ultimately eradicate it.

Results

In 2008, ECISMA applied and received a \$25,000 grant from the Everglades Foundation (Palmetto Bay, FL, USA), a non-profit organization, to implement the African Sacred Ibis EDDR plan. These funds were primarily distributed to Zoo Miami, a non-government organization, US Department of Agriculture-Wildlife Services (USDA WS), a Federal non-regulatory wildlife management agency, and the Florida Fish and Wildlife Conservation Commission (FWC), a State wildlife regulatory and management agency (Constantin 2008).

In 2008, Zoo Miami and ECISMA members began simultaneous efforts to capture and remove as many African Sacred Ibis as possible. Thirty-three birds were captured by baiting existing covered holding pens, erecting enclosures around feeding stations, and orally administering sedation drugs. Attempted sedation, under veterinary supervision, on isolated individuals with Telazol solution injected into fish delivered orally was mildly successful with the subsequent hand net capture of a few mildly sedated individuals (Janovsky et al. 2002). The majority of attempts resulted in quick regurgitation of the fish with no observable effects, learned avoidance behavior, and the methodology was discontinued early in the capture program due to expense and low success rate. Capture events spanned July 26 through December 24, 2008, and all captures took place during twenty days within this span. All methods were employed in a manner aimed to maximize target species captures while minimizing probability of non-target species captures (Avery and Feare 2020).

The first two African Sacred Ibis captured on July 26 and 27, 2008, were transferred to USDA WS and fitted with 70g backpack GPS transmitters (Microwave Telemetry, Isanti, MN, USA) (Figure 2) in order to employ the "scout" technique, leveraging the behavior of radio tagged individuals to aid in locating conspecifics by revealing their location so they can be subjected to removal (Woolnough et al. 2006; Smith et al. 2016; Fitzgerald et al. 2021). Satellite based location data from these two birds indicated they roosted on an island at the Calusa Country Club (CCC), Miami-Dade County, 11.3 km north from Zoo Miami. Monitoring this roost then led to the discovery of a larger African Ibis population in the Kendall District of southern Miami.

Also occurring in 2008 was an African Sacred Ibis outreach effort, led by ECISMA. This effort targeted natural resource management personnel conducting field work in South Florida, requesting they report any observed African Sacred Ibis. In addition, partnerships were created with



Figure 2. Two African Sacred Ibis (*Threskiornis aethiopicus*) affixed with wing tags and GPS backpack transmitters in September of 2008 in order to employ the “scout” technique as part of a successful southern Florida, USA, eradication effort. Photo courtesy of USDA.

several local birding groups, including Florida Audubon, in order to increase awareness and establish a network for observing and reporting sightings. This outreach appeared to increase overall reported sightings and led to the discovery of African Sacred Ibis frequenting landfills in both Palm Beach and Miami-Dade counties. Equally important, the outreach to Audubon and their subsequent support in the local media was key to showing the public the eradication effort was consistent with bird conservation.

The 33 African Sacred Ibis captured by Zoo Miami were surgically pinioned, rendering them permanently flightless to avoid any further possibility of reintroduction into any susceptible environments. These birds were then placed with other accredited zoological facilities in North America with signed agreements that outlined the invasive potential of the birds and need for containment. Also in 2008, USDA WS implemented lethal take by way of shooting on Zoo Miami grounds and the surrounding areas, determined by the scout technique and reported sightings. A total of 45 Sacred Ibis were lethally removed. Lethal removal took place after dusk.

Ninety percent of these birds were removed with a low velocity suppressed .22 caliber rifle using standard bullets and red light and 10% were removed with a 12 gauge shotgun using #7 steel shot. Use of night vision was attempted but USDA WS wildlife specialists found that the resolution was not clear enough to readily distinguish African Sacred Ibis from other species of co-roosting waterbirds (Jerry Hairston, USDA WS, *personal communication*). Maximum firing distance at Zoo Miami, where the majority of birds were taken, was 20 meters. A two-person team of USDA WS wildlife specialists was the standard for lethal removal efforts. The number of birds lethally removed from Zoo Miami, Palm Beach County

Landfill, Miami-Dade County Landfill, Cutler Wetlands, and Old Cutler Road sites were 28, 13, 2, 1, and 1 respectively. In November 2009, two African Sacred Ibis were sighted and removed by USDA WS in Tropical Park in Miami-Dade County that had silver leg bands, likely representing another independent introduction event from a private collection. As of 2022, only two other confirmed sightings of African Sacred Ibis have been reported within the greater Miami area, with those occurring in 2011 (University of Georgia, Center for Invasive Species and Ecosystem Health 2022); these birds were quickly dispatched via the EDRR procedures in place.

Discussion

We provide a rare example of an eradication of a founder population of an avian species and outline the collaborative network and strategies employed to make the eradication effort successful. Several criteria made this effort possible. Firstly, an independent university researcher (Florida Atlantic University) with one to three teams of students conducting field research on wading bird colonies acted as early sentinels documenting the spread of the species into the natural system and then acting to assess the risk of establishment. Secondly, because the population was detected at the founder stage, it was possible for the rate of removal to be greater than the reproductive rate of the population (Bomford and O'Brien 1995). Thirdly, because the area being utilized by the African Sacred Ibis was relatively limited in spatial extent despite being on the mainland, all animals were susceptible to management, with management efforts successfully taking place on both public and privately owned land. This criterion likely would not have been met without the leveraging of the “scout” technique and a robust framework for collecting and acting upon reported sightings of the species by both private citizens and natural resource professionals. The “scout” technique has been applied to passerine birds (Woolnough et al. 2006), but to our knowledge we are the first to report on the application of this technique for a large wading species or for any avian invasive species in the Greater Everglades. Also key to this effort was the availability and acquisition of grant funds which initiated on-the-ground efforts and also recompensed satellite transmitter monitoring costs.

In addition to the above, the collaboration for this effort and outreach to conservation groups were paramount to its success. The project involved university researchers and non-profit conservation organizations utilizing existing resources and another allocating funds to State and Federal governmental wildlife agencies to take rapid action. For USDA WS, this allocation of funding was pivotal, as the agency, unlike the majority of Federal wildlife agencies, is largely a fee for service program. Though Zoo Miami and USDA WS were the primary parties responsible for physical removal efforts, having the regulatory agency, FWC, integrally involved with the entire project ensured all phases took place in a timely manner

that complied with all State regulations. Also, we believe the deliberative action of utilizing non-lethal methods for removing a sizable percentage (33 of 78, 42%) of the founder population was key toward keeping public opinion and support for the project positive. The gut contents of all lethally removed birds were donated to other research organizations where they provided a deeper understanding that this species' ability to exploit anthropogenic food resources was likely the basis for its expansion out of the Miami area (Calle and Gawlik 2011).

Because this effort was successful at removing the founder population, it is not possible to determine to what extent the population would have expanded numerically and spatially. It is also not possible to quantify the ecological and economic impacts that the population's establishment would have engendered. There was concern that establishment in the Greater Everglades by this large wading bird would put pressure on the larger bodied federally endangered (at the time) Wood Stork (*Mycteria americana*), and the smaller bodied White Ibis (*Eudocimus albus*), through nestling predation and resource competition (Williams and Ward 2006; Herring and Gawlik 2008). In addition, Herring and Gawlik (2008) used demographic parameters from established invasive African Sacred Ibis populations in Europe and determined a 73% probability for the species becoming established in southern Florida if left to an unchecked population trajectory. Given that established populations of African Sacred Ibis in Europe and Taiwan originated from small founder populations, we urge that invasive species managers faced with an African Sacred Ibis founder population adopt the Precautionary Principle (Rogers et al. 1997), as we did here. Since the South Florida African Sacred Ibis eradication, sporadic sightings of the species have occurred in other parts of Florida (University of Georgia, Center for Invasive Species and Ecosystem Health 2022), but a current long-term agreement between FWC and USDA WS is in place to promptly remove non-established invasives.

Eradications of founder populations of avian species on mainland environments have previously occurred, although rarely, including several instances for African Sacred Ibis in Europe (see Avery and Feare 2020). However, to our knowledge, here we are the first to provide a detailed account on such an eradication occurring on a mainland portion of the North American continent.

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Author's contribution

BMK: research conceptualization, writing – original draft; MLA: research conceptualization, investigation and data collection, writing – review and editing; DEG: research conceptualization, review and editing; PH: research conceptualization, investigation and data collection, review and editing; JH: research conceptualization, investigation and data collection, review and editing; TP: research conceptualization, investigation and data collection, review and editing; FR: research conceptualization, investigation and data collection, review and editing.

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