# INTO THE FUTURE OF URBAN WHITE IBIS POPULATIONS: FLEDGLING MOVEMENT, HABITAT SELECTION, AND PATHOGEN DYNAMICS AND CONSIDERATIONS ON HUMAN-IBIS INTERACTIONS

by

JULIA SILVA SEIXAS

(Under the Direction of Sonia M. Hernandez)

## ABSTRACT

Urbanization is rapidly transforming natural habitats, compelling species to adapt to novel and dynamic landscapes. Wading birds in particular present a unique opportunity to promote coexistence between wildlife and humans in shared urban spaces because of their limited involvement in human-wildlife conflicts and their general acceptance by the public. This dissertation aimed at filling the gaps in the urban ecology and human dimensions of an abundant wading bird in south Florida so more informed conservation strategies can be used to promote coexistence between wading birds and humans in urban areas. Critical aspects of post-fledging movement, habitat selection, pathogen exposure, and human-wildlife interactions were examined on White Ibis (*Eudocimus albus*) in south Florida. Using high-resolution GPS tracking, juvenile ibises from two urban colonies were monitored during their post-fledging period. Analyses revealed distinct movement patterns, with individuals alternating between resident movement and broader exploratory nomadic patterns. Concurrently, targeted pathogen assessments demonstrated a significant prevalence of waterborne bacteria, specifically *Vibrio* and *Salmonella*, among fledglings and in their natal colonies. These findings suggest that urban landscapes may facilitate recurring cycles of infection and reinfection, positioning juvenile ibises as potential transporters for pathogen transmission between human-dominated and natural ecosystems without significant impacts on mortality as suggested by survival models. Additionally, a survey was deployed to south Florida residents to explore the motivations behind supplementary feeding of ibises. Results indicated that approximately one-third of respondents engage in feeding practices, driven primarily by personal enjoyment, companionship, and stress relief, despite limited awareness of the ecological repercussions. Such practices may inadvertently alter natural foraging behaviors and elevate pathogen exposure, thereby impacting urban ibis population health and ecology. This study offers a comprehensive framework for understanding how urbanization shapes the ecology of ibises. By bridging movement ecology, disease dynamics, and human dimension studies, this research provides critical insights for developing management strategies aimed at fostering sustainable coexistence between humans and urban-adapted wading birds.

INDEX WORDS: wading birds; urbanization; movement ecology; infectious diseases; public opinions; human-wildlife coexistence

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# DEDICATION

Dedico este trabalho à minha mãe, Ana Lucia Leite e Silva, que sempre me apoiou e que possibilitou meus estudos desde a escola até este momento. E agora e daqui para frente também nos negócios. Eu não vivo sem meu favo de mel.

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# CHAPTER 1

# WADING BIRDS AS FOCAL SPECIES IN BIOPHILIC CITIES: CHALLENGES AND OPPORTUNITIES[1]

[1] Seixas, J. S., Hernandez, S. M. To be submitted to a peer-reviewed journal.

# ABSTRACT

Biophilic cities aim to reconnect urban environments with nature, creating spaces that promote biodiversity, improve human well-being, and address environmental sustainability. Integrating wildlife into urban spaces presents opportunities for people to connect with nature, offering psychological benefits and promoting an appreciation for conservation. Many wading bird species perform critical roles in their natural ecosystems and are frequent targets of surveillance and conservation initiatives. For many species, urban spaces represent a critical alternative habitat. With their charismatic appeal and general avoidant behavior, wading birds are ideal species to integrate into urban ecosystems. Despite the ecological and societal benefits, the receptivity of wading birds in urban areas is still challenging. Conflicts raised by property damage, health concerns, and direct encounters with humans are not uncommon and are thus compounded by negative public perceptions, sometimes reinforced by media narratives that frame these birds as pests. Management and public education strategies that align with biophilic urbanism principles can be readily employed to address and prevent these conflicts. Habitat modification, such as designing urban wetlands and green spaces, that accommodate wading birds while mitigating conflicts, is a key solution. Public education and community engagement are also critical to reinforce positive attitudes. To accomplish coexistence between wildlife and humans in shared urban spaces, collaborative efforts among researchers, policymakers, and urban planners are critical to develop innovative solutions that balance human interests with wildlife conservation. Herein I discuss common human-wading bird conflicts and provide evidence-based strategies for achieving coexistence between wading birds and humans, highlighting how urban landscapes can be designed to balance ecological functionality with societal demands. By aligning urban planning with conservation principles, cities can serve as

dynamic systems that sustain biodiversity and facilitate positive relationships between humans and wildlife.

## INTRODUCTION

Biophilia is an increasing trend in urbanism that gained traction in the 2010s. Biophilic cities 1) are cities of abundant nature and natural experiences; 2) are biodiverse; 3) are multisensory; 4) are cities of interconnected integrated natural spaces and features; 5) immerse us in and surround us with nature; 6) are outdoor cities; 7) embrace the marine and aquatic as well as the terrestrial; 8) celebrate the small and the large – from the microscopic to the celestial; 9) are cities where citizens care and are engaged with nature; 10) foster a profound curiosity; 11) care about and nurture other forms of life; 12) care about nature beyond their borders; 13) invest in nature; 14) are inspired by and mimic nature; 15) exhibit and celebrate the shapes and forms of nature; and 16) seek an equitable distribution of nature and natural experiences (Beatley 2017). According to this definition biophilic cities create green spaces, while also thriving to instill conservation values in their citizens. Examples of cities that invest in biophilia include Austin, Barcelona, and, most notably, Singapore (Biophilic Cities 2024). Coexistence with urban wildlife is indispensable in this model and is thus both a consequence of its implementation and an asset to be pursued. The increasing demand for the incorporation of biophilia in urban spaces is reflective of the recent understanding of the psychological benefits of increased exposure to nature and outdoor lifestyles and the intensification of conservation values (Grinde and Patil 2009; Perry et al. 2020; Hung and Chang 2021). This creates a demand for increased contact with wildlife, creating challenges in conflict prevention and mitigation.

The growing abundance of urban wildlife resulting from the expansion of urban development globally provides important challenges towards coexistence. Human-wildlife conflicts and concerns often result in the management of problematic species. Notorious human-wildlife conflicts typically involve mammals (e.g., bears, coyotes, raccoons) and reptiles (Nyhus 2016). Conversely, within vertebrates, birds, particularly songbirds, are among the few species that are often intentionally attracted by people living in cities. In fact, over US$5 billion is spent on feeders/bird houses and supplementary feed for birds annually (U.S. Fish and Wildlife Service 2016). Birds are desirable for their aesthetics and songs, but become problematic when they are overabundant, damage private property (e.g., through defecation roosting and nest building), adopt behaviors, such as harassing people for food, or are associated with diseases. Waterbirds are a group comprising of species that are frequently associated with conflicts while still being commonly desired in public areas and personal backyards. In fact, waterfowl conflicts are widely discussed in the literature (Coluccy et al. 2001; Callaghan et al. 2015; Fox et al. 2017), yet, many people raise domestic waterfowl species as pets. Although not usually considered pets, wading birds are also species that are generally desired in public spaces while also being prone to cause some conflict.

Found globally, wading birds are important for ecosystem maintenance, often functioning as bioindicators. Wading birds are easy to spot, are well-studied, often nest in large numbers, and respond rapidly to minute changes in their habitat (Frederick et al. 2009). They are also found in a variety of ecosystems including wetlands, coasts, grasslands, and urban areas, allowing them to function as focal species in habitat quality assessments, climate change models, and bird conservation frameworks (Butler and Vennesland 2000; Xie et al. 2024). For these reasons, wading bird research is key to the conservation agenda. Increasing habitat loss and fragmentation are pushing the urbanization of more wading birds globally. Their role in natural systems and the decline in natural population puts pressure on the conservation of urban populations, making wading birds an interesting case that stirs discussions on their presence in urban areas (Hunt 2016; Watts and Watts 2018).

In urban areas, wading birds are common in spaces where natural or artificial water sources are abundant. They are aesthetically pleasing birds, attracting local bird and nature enthusiasts and providing urban communities with opportunities of close encounters with medium-sized fauna. Wading birds also generally avoid direct contact with people and are thus less likely to become aggressive towards humans. The accessibility to, and wellness benefits of, wading birds make them a particularly desirable taxa to target in biophilic city designs. Conflicts caused by wading birds are few, but not negligible. Economic impacts of damage caused by wading birds are more pronounced in the aquaculture industry, where losses were estimated between $7200-44640 per farm annually (Hoy 2017). In cities, conflicts with wading birds are mostly related to their breeding sites, but can also include nuisance behaviors, such as stealing food from people, damage to property, noise, and fecal contamination of surfaces. Wading birds are important wildlife to include in biophilic city agendas, both for their contribution to human well-being and conservation impacts. Conflicts are often shaped by ecological, economic, and cultural factors, highlighting the need for nuanced, context-specific solutions (McMahon et al. 2024). Therefore, a thorough understanding of conflicts involving wading birds and how to avoid and mitigate them is necessary to allow for their coexistence in urban landscapes. Here I present a summary of reported human-wading bird conflicts in urban areas, how they are currently managed, how conflicts can be prevented and mitigated, and how we can promote coexistence.

## CONFLICTS

### *Breeding Colonies*

Wading birds usually nest in colonies sometimes referred to as heronries. Colonies are formed between single or multiple species that often aggregate in woody vegetation surrounded by water, with nest numbers sometimes reaching hundreds of thousands in natural environments (Cocoves et al. 2020). Urban colonies tend to be smaller but can also attract thousands of nesters (Hattori 2006; Rihane et al. 2020). These rookeries can be found in highly urbanized areas, in locations including residential communities, gardens, golf courses, parks, zoos, and the land surrounding rehabilitation centers (Hattori 2009; Gohel et al. 2021; Seixas 2021). Urban colonies can provide numerous benefits to wading birds, particularly those declining in their natural habitat, like Yellow-crowned Night Heron (*Nyctinassa violacea*) populations in Virginia and Black-crowned Night Heron (*Nycticorax nycticorax*) populations in Illinois (Hunt 2016; Watts and Watts 2018). Some species can readily adapt to breeding in a novel environment. In fact, even a near threatened species, the Black-headed Ibis (*Threskiornis melanocephalus*), was observed to be habituated to human presence (Dwevedi et al. 2018). Productivity at these sites can be high for many species because 1) urban areas can provide continuous and reliable access to food and 2) predation rates of young can be lower (Roshnath et al. 2019; Gohel et al. 2021; Seixas 2021). Urban colonies were proposed to function as buffers for Wood Storks (*Mycteria americana*) in Florida, providing minimal annual recruitment even in years of poor foraging conditions at natural sites (Evans and Gawlik 2020).

Nuisance caused by colonies is typically resultant from their noise, odors, and the health concerns they raise (Grant and Watson 1995; Telfair et al. 2000; Hattori 2009). For example, a Yellow-crowned Night Heron colony located in a park in San Antonio Texas sits over dining spaces, sidewalks, and a river that is regularly used for tours, making these areas notorious for frequent droppings from nests in the trees above. Visitors to this area need to be cognizant of this problem, as birds are well habituated to the heavy human traffic (Boal 2010). Health concerns are specifically heightened by the persistent presence of adult and nestling carcasses. Additional reasons for colonies to be described as nuisances include the 1) persistent presence of birds in the area, which intensifies the accumulation of feces in houses, parked vehicles, and lawns, 2) damage to private lawns and landscaping, which can rapidly elicit local management, and 3) presence of fledglings in undesirable locations e.g., private garages and porches (Grant and Watson 1995; Telfair et al. 2000; Parkes et al. 2012). Despite discontent with wading bird colonies, the public may still see value in wading birds and advocate for their conservation, highlighting opportunities for conservation campaigns to increase tolerance (Roshnath and Sinu 2024).

### *Damages*

Removal or significant alteration of vegetation for nest building and the accumulation of droppings from colonies can cause a lot of damage to vegetation and soil (Grant and Watson 1995; Craig et al. 2012). For example, species such as post oak (*Quercus stellata*) and black locust (*Robinia pseudoacacia*) are highly sensitive to nutrient overload from bird feces, which can lead to a rapid decline in these plant populations (Grant and Watson 1995). Impacts of nesting by wading birds can leave areas barren by the end of the nesting season, affecting not only the vegetation but also other wildlife species that depend on these habitats. For instance, the removal of nesting Australian White Ibis (*Threskiornis molucca*) led to a resurgence in the endangered Richmond Birdwing Butterfly (*Ornithoptera richmondia*) in one remnant rainforest patch in Queensland (Ross 2004). Craig et al. (2012) also reported that arthropod communities in urban waterbird nesting areas are distinct, with decomposers being favored over plant feeders. They also found that vegetation loss and shifts in community structures are more pronounced among older and denser colonies. Changes in plant and wildlife communities are particularly in parks and backyards that prioritize landscaping for its aesthetics. Wading birds are known to feed regularly in backyards, which can be problematic for residents with pet fish in their ponds (Hoy 2017).

The perching and roosting behavior of wading birds, such as the Hadeda Ibis (*Bostrychia hagedash*) and the African Woolly-necked Stork (*Ciconia microscelis*), on house roofs, poles, and other urban structures can also lead to significant issues due to the accumulation of droppings (Singh and Downs 2016; Thabethe and Downs 2018). This not only causes unsightly stains, but also potential damage to roofing materials, contributing to increased maintenance costs for homeowners. Additionally, the deposition of large amounts of feces in concentrated areas can create health concerns and unpleasant odors, making these birds undesirable in some urban settings (Fig. 1.1).

White Storks (*Ciconia ciconia*) have significant impacts within anthropogenic areas through their nesting behaviors. Their large nests, which can weigh between 70 kg and 1400 kg and exceed a meter in diameter, frequently cause structural damage to buildings, chimneys, and power lines (Fig. 1.2; Moreira et al. 2018; Burdett et al. 2022). On power lines, these nests present severe risks, including power outages caused by removal of material for nest building, fallen debris, and blackouts due to fecal contamination of insulators (Burdett et al. 2022; Moreira et al. 2023). In Portugal, White Storks can be responsible for 50% of power outages along the distribution grid, illustrating the economic burden associated with this species (Moreira et al.

2018). Additionally, the accumulation of droppings can result in damage to historic buildings, which is especially relevant to specific sites in Europe.

The presence of wading birds around airports, particularly those that forage, roost, or nest near runways, can pose significant risks to aviation safety (Paton et al. 1986; Robinson et al. 2021). Bird strikes involving wading birds can lead to substantial financial losses and serious safety hazards for both aircraft and passengers. Wading bird habitats created through dredged material deposition near airports also pose a significant risk of bird strikes, as these areas can attract large concentrations of birds (Guilfoyle and Fischer 2011).

### *Nuisance Behaviors*

There can be many attributes contributing to the likability of a species, including their aesthetic appearance, local abundance, and behaviors, with the latter being a key determinant of the establishment of a species as a nuisance (Barnes 1993; Weiss Reid 2003). Beyond destruction of property, some wildlife populations, including wading birds, are currently considered nuisances resulting primarily from direct encounters with people (Johansson et al. 2024). The Australian White Ibis has become highly adaptable to urban environments in southeastern Australia by utilizing human-provided food sources, such as waste from landfills, bins, and discarded food (Ross 2004). This gave them notoriety as “trash birds” (or colloquially, “bin chickens”), which is attributed to public perceptions of disgust (Allatson and Connor 2023; Scollen 2024). Additionally, scavenging trash and regularly foraging at landfills can also be associated with health concerns, as birds can scatter waste and potentially transport pathogens (Osorio et al. 2024). Urban ibises also adopted nuisance behaviors, including snatching food from people in public areas and harassing them for food, often causing the public discomfort and concern (Ross 2004).

Most wading birds are not known for their vocalizations, especially outside of breeding colonies. However, some species can cause conflict resultant from noise. In suburban neighborhoods of Pietermaritzburg, South Africa, Hadeda Ibises have been observed perching on house roofs and poles, as well as foraging on lawns, particularly those that are well-watered. They regularly communicate with conspecifics via loud vocalizations, which can be quite burdensome when done early in the morning. The birds' persistence in urban spaces, while demonstrating adaptability, often leads to conflicts with residents (Singh and Downs 2016).

### *Role In Zoonotic Diseases*

The perceived health risks associated with wading birds can have a substantial impact on management strategies (Sarlin et al. 2022). Public concern about zoonotic diseases often leads to negative attitudes towards these birds and can result in demands for control measures, including culling or relocation. These management responses are frequently driven more by perception than by a robust evidence base, highlighting the importance of informed decision-making based on epidemiological data to ensure appropriate and effective interventions (Maute et al. 2019). Nonetheless, wading birds share a number of pathogens with humans, which can either experience significant mortality from them or play an important role in pathogen transmission.

Wading birds, particularly ardeids like herons and egrets, are recognized reservoirs and potential amplifiers of vector-borne pathogens such as Japanese encephalitis virus and West Nile virus (WNV; Mishra et al. 2012; Walsh et al. 2022). Although uncommon, mortality events associated with WNV have been recorded at an urban colony of White Ibises (*Eudocimus albus*) in South Florida (Seixas et al. 2022). Urban colonies were previously proposed as focal points for WNV transmission; however, this statement lacks supporting evidence (Reisen et al. 2009). Wading birds are also regularly exposed to avian influenza (AI) in urban environments (Epstein et al. 2006; Bahnson et al. 2020). Studies addressing the role of wading birds in AI dynamics are limited compared to other water birds, however, evidence from virus isolation, PCR, and serological assays across many species suggest their potential role as reservoirs, particularly in urban environments (Wang et al. 2014; Bahnson et al. 2020; Shriner and Root 2020; Soda et al. 2022). It was also proposed that wading birds might play a minimal role in AI virus transmission, but they might be more relevant in urban environments and along migratory routes (Müller et al. 2009; Woo et al. 2017). Urban wading birds can also act as important reservoirs and carriers of zoonotic bacteria such as *Escherichia coli*, *Salmonella*, and *Vibrio* (Epstein et al. 2006; Hernandez et al. 2016; Telesford-Checkley et al. 2017; Seixas, unpublished data). For example, urban White Ibises were found shedding *Salmonella* at higher rates than their natural counterparts (Hernandez et al. 2016). Exposure risks to these birds were linked to a higher foraging site fidelity to urban sites such as parks and zoos and transmission pathways were hypothesized to be primarily driven by environmental uptake, rather than direct transmission between hosts (Becker et al. 2018; Murray et al. 2021). Wading birds can also act as reservoirs and vectors of antibiotic-resistant bacteria, particularly in environments influenced by anthropogenic activity (Bouaziz et al. 2018; Höfle et al. 2020). Additional urban wading bird mortalities were reported in Jacksonville, Florida, which involved an outbreak associated with *Eustrongylides* spp. in juvenile Great Egrets (*Ardea alba*) and Black-crowned Night Herons (*Nycticorax nycticorax*). This parasite poses a zoonotic risk as it can be transmitted through contaminated fish, potentially affecting humans who come into contact with contaminated water or food. The parasite thrives in nutrient-rich, eutrophic conditions commonly found in urban water bodies, placing urban populations at a particularly higher risk of exposure (Caudill et al. 2014).

### *Management Strategies*

Management practices of urban wildlife populations often resemble techniques implemented on natural populations however, in contrast to the latter, demand for urban wildlife management mostly stems from inherent characteristics of each species i.e., its presence is an inconvenience to humans. Effective management of bird conflicts requires a multifaceted approach, that integrates ecological knowledge with stakeholder engagement to address uncertainties and build trust (McMahon et al. 2024). The control of urban wading bird populations may involve lethal control, active deterrents (e.g., pyrotechnics), relocation, habitat modifications, such as reducing nesting materials, modifying access to anthropogenic food sources, and creating buffer zones to minimize conflicts (Hattori 2006; Perry et al. 2020; Willis et al. 2024). For example, responses to control urban Australian White Ibis populations have included culling, removing nests, egg oiling, and altering landfill sites to reduce the availability of food (Ross 2004). Active interventions to disturb and displace nesting colonies have also been employed, however these practices may cause the population to spatially disperse and may also result in ibises becoming more wary, making management more difficult. More effective methods have focused on reducing access to nesting materials and modifying environments to discourage nesting in the first place. For example, completely removing nests and nesting materials from urban palm trees has been effective in preventing the re-establishment of colonies in heavily urbanized areas (Ross 2004; Willis et al. 2024).

Responses to deterrents can vary greatly between species and populations. For instance, contrary to the Australian White Ibis example, Hattori (2006) demonstrated that passive methods, such as deploying Mylar strips, scare balloons, and tree pruning, were largely ineffective in deterring urban-nesting egrets and herons in Davis, California. In this case, active hazing methods, including lasers and pyrotechnics, were significantly more effective in preventing colony establishment. While visual and auditory deterrents can be effective at first, wading birds can quickly become habituated, demanding the adoption of alternative techniques (Hoy 2017). To address this, the employment of pyrotechnics is performed in conjunction with falconry practices to deter White Storks from landfills, a combination that has been shown to avoid habituation. However, careful evaluation of indirect consequences from deterrents is warranted, as these activities can have important consequences on target species productivity and fitness (Osorio et al. 2024).

Management of nuisance wading birds is usually difficult to implement because many species are protected by law, requiring permits for habitat modifications (Grant and Watson 1995). This legal constraint means that management options are limited once nests are constructed and eggs are present, impacting the ability to address conflicts effectively. For this reason, management usually includes discouraging the reuse of established colonies and discouraging nesting as soon as birds arrive on site (Telfair et al. 2000; Parkes et al. 2012; Hoy 2017). Wading bird nesting sites are often difficult to predict, thus relying predominantly on reactive interference. To address this constraint, Telfair et al. (2000) highlighted the value of active community involvement, by training local personnel and volunteers in identifying early signs of potential nuisance colony development to ensure timely intervention before its establishment.

Mitigation strategies for minimizing wading bird aircraft strike hazard near airports include habitat modifications to make areas less attractive to wading birds and sometimes culling (Froneman 2000). These measures can involve altering the availability of roosting sites or modifying water sources and lawns to prevent large congregations of birds near runways. Such strategies are essential in reducing the risk of bird strikes (Guilfoyle and Fischer 2011).

## COEXISTENCE

### *Preventing and Mitigating Conflict*

The interplay of the impacts of climate change and natural habitat deterioration is likely to drive the urbanization of more wildlife species while also promoting an increase in abundance of those that are already urbanized, leading to potential escalations of human-wildlife conflicts (Willis et al. 2024). Conflict prevention demands careful examination of the target species, its habitat requirements, current public perceptions, and the urban landscape. In summary, wading bird conflicts can be addressed through habitat modifications and public outreach.

Modifying habitat in areas where wading birds are not desirable is a valuable way to prevent or mitigate their establishment. For instance, wading birds are particularly attracted to shallow water bodies where prey can be easily captured. Maintaining ponds at higher depths and reducing vegetation near the water, particularly around the edges, can be an effective way to reduce local wading bird abundance. Additionally, backyard ponds can be enclosed with netting or wire mesh to protect pet fish from predation (Hoy 2017). Urban planning could also incorporate vegetated areas with suitable perching sites, located away from potentially problematic areas, such as airports, to support wading bird populations while minimizing conflicts. Managing landscape connectivity and designing urban areas with habitat diversity are important measures to alleviate human-wildlife conflicts by encouraging dispersion. Strategic urban planning could also focus on waste management and minimizing access to anthropogenic food resources to limit wading bird distribution near residential areas (Willis et al. 2024). Concerns about infectious disease transmission can be addressed by maintaining urban colonies away from densely populated spaces (e.g., restaurants and residences), since these sites are commonly regarded as health hazards.

Early intervention is crucial to avoiding conflicts before they escalate, as public perception can be rapidly shaped by negative interactions with urban wildlife. As Thabethe and Downs (2018) noted, “many of today’s nuisance/problematic birds in urban areas were once encouraged by urban residents”. The Australian White Ibis provides an important case study on how quickly public perceptions can shift when a species becomes established in urban areas and their behaviors begin to conflict with human expectations or convenience. Originally seen as a “farmers' friend” for controlling agricultural pests, the ibis has now earned the derogatory nickname “bin chicken” due to its scavenging behavior in cities (Allatson and Connor 2023). This evolution in perception underscores the need for early conservation actions and proactive public education measures since, once a species is seen as a pest, it is significantly harder to reverse that perception. Opinions are further reinforced by the media, which still commonly uses negative terms such as “pests” and “bin chicken”, but also “victim” to refer to the ibises (Scollen 2024). However, new positive terms, including “survivor” and “hero”, were introduced in 2017, and they have since been gaining more space in media narrative, reflecting yet another change in public perception. This recent movement was likely influenced by the recent adoption of the bird in local popular culture, but also by a potential push from media outlets towards a more empathetic view of this species. These shifts in media narratives highlight two critical points.

First, they demonstrate how language and representation in public discourse influence societal attitudes toward urban wildlife. The transition from disdain to admiration for the ibis shows that public empathy can grow when narratives emphasize resilience, ecological contributions, or cultural significance. For example, describing the ibis as a “hero” has helped reframe their scavenging behavior from a nuisance to a testament to adaptability, aligning with Australians' cultural affinity for *underdog* figures (Scollen 2024). Second, this case underscores the role of storytelling in promoting coexistence between humans and urban wildlife. Positive narratives can pave the way for increased tolerance and support for coexistence strategies. When urban species are no longer viewed solely as nuisances, but as integral participants in urban ecosystems, it becomes easier to implement measures that balance human and wildlife needs. As Allatson and Connor (2020) noted, the ibis’ emblematic status in cities is challenging traditional notions of urban spaces as human-centric by reinforcing new narratives of coexistence. Like the Australian White Ibis, other urban wading birds are often perceived through a lens of conflict, particularly when their nesting or foraging behaviors interfere with human activities. However, reframing their presence in cities as an example of ecological resilience and adaptability can shift public perceptions. Media campaigns, educational programs, and community engagement efforts could use these positive narratives to promote appreciation for the ecological roles of wading birds, such as their contributions to controlling pest populations, maintaining wetland ecosystem balance, and serving as sentinels for environmental antibiotic resistance and diseases of public health relevance (Nachuha et al. 2014; Seixas et al. 2022; Walsh et al. 2022; Lin et al. 2023).

Encouraging public tolerance and acceptance of urban wildlife does not rely exclusively on conservation and public education campaigns. Increasing efforts to make cities more “natural” and welcoming towards wildlife can have a critical role in preventing human-wildlife conflicts. In fact, exposure to wildlife since childhood was described to make urban citizens more tolerant to nuisance wildlife later in life (Hosaka et al. 2017) while a lack of exposure may lead to declining support for conservation (Miller 2005; Soga and Gaston 2024). Limiting wildlife feeding in urban areas is an essential strategy for mitigating or preventing the adoption of nuisance behaviors (e.g., harassing the public for food) by wading birds while also reducing health risks associated with them. Enforcement of feeding regulations, public education, and understanding the motivations behind feeding behavior can potentially discourage nuisance behaviors and decrease pathogen prevalence in wading birds and associated public health risks (Murray et al. 2021).

### *Creating Habitat*

Urban wading birds are capable of showing incredible resilience and adaptability. They can be readily attracted to areas offering water and foraging habitat, making parks (including municipal parks), golf courses, zoos, and residential backyards, artificial landscapes where these birds are commonly found. Key habitat features, including aquatic vegetation, water bodies with shallow edges (< 20 cm), shade, proximity to other habitat patches, reduced disturbance (e.g., landscaping, construction), and even lawns, can significantly influence the foraging success of wading birds (Fig. 1.3). For instance, wading bird assemblages showed higher foraging activity in areas where these criteria were met, however species-specific habitat preferences may vary, warranting targeted research and management (Traut and Hostetler 2004; Collins and Mulley 2005; McKinney and Raposa 2013). In addition to artificial freshwater wetlands, urban marine habitat can also be a significant resource for some wading bird species, such as Great Egrets, and pose as better foraging grounds than e.g., rural sites (McKinney and Raposa 2013). Wading birds can accommodate their distribution based on public receptivity by persisting in urban spaces while avoiding areas where they are frequently deterred from, enabling city planners to mitigate conflicts through targeted urban design (Watts and Watts 2018). Compared to natural wetlands, these artificial habitats provide low concentrations of prey that are insufficient to support large numbers of wading birds but are likely essential to supply their anthropogenic diets with necessary nutrients and protein without the need to regularly cross back to natural areas (Murray et al. 2018; Evans and Gawlik 2020; Kidd-Weaver 2020). However, developed areas can act as ecological sinks by concentrating pollutants such as pesticides and heavy metals, which can accumulate in artificial water bodies and urban wetlands, posing health risks to wading birds. For example, elevated levels of heavy metals such as lead and mercury have been found in urban wetlands and they can cause significant physiological and reproductive issues in birds (Heath and Frederick 2005; Parsons et al. 2010; Sharley et al. 2017). Pesticides used in landscaping and pest control can also accumulate in aquatic systems, leading to contamination of prey species, which then affects wading birds that rely on these food sources (Nottingham et al. 2021; Pettigrove et al. 2023).

Beyond toxicants, urban water bodies can expose wading birds to important pathogens. Parasites such as *Eustrongylides* spp. thrive in eutrophic conditions caused by treated sewage and nutrient pollution in urban watersheds (Coyner et al. 2003). These parasites can lead to severe health issues for wading birds and pose zoonotic risks, affecting humans and domestic animals that come into contact with contaminated water or prey (Caudill et al. 2014). Similarly, avian botulism is a critical concern in urban wetlands that receive treated wastewater (Badagliacca et al. 2018; Anza et al. 2014). Eutrophication in these environments, driven by increased nutrient load, low oxygen levels, and decaying vegetation, creates favorable conditions for the proliferation of *Clostridium botulinum*, the bacterium responsible for avian botulism. Avian botulism outbreaks are notorious in waterfowl, but they can also lead to significant mortality among wading birds that frequently use these water bodies (Brandis et al. 2019). Effective urban management should focus on controlling water quality to minimize these risks, emphasizing the reduction of nutrient pollution from treated wastewater and improving hydrology and plant community composition of urban wetlands (Greenway and Simpson 1996). Such proactive measures are essential to mitigate risks and ensure a healthier environment for both wildlife and humans.

Integrated management approaches that balance nature conservation with anthropogenic uses can be crucial for urban planning. Clausen and Bregnballe (2022) highlight the importance of proactively identifying and protecting critical areas for wading birds, which could similarly be applied in urban spaces to support their ecological needs. Strategic spatial planning can incorporate features like vegetated areas with suitable perching sites that are away from potentially problematic areas, provide buffer zones around important colonies, roosts, and foraging sites, and limit disruptive activities near key habitats (Rodgers and Schwikert 2002; Clausen and Bregnballe 2022; Willis et al. 2024). To address aviation safety, Andersson et al. (2017) recommends situating wetlands outside government-established safeguarding zones, e.g., 8 km in the US, around aerodromes whenever possible. These measures are essential to create suitable environments for wading birds and facilitate their long-term presence in urban areas. Biophilic recreational activities need to also be carefully planned to not interfere with key nesting and foraging habitat. Public education should also target bird-friendly recreation, e.g., kayaking at least 100 m away from the edge whenever possible (Arrieta et al. 2016). Creating nesting habitat is a valuable strategy to support wading bird populations, particularly those threatened by habitat loss due to urban expansion. However, integrating wading bird colonies into urban spaces can still be challenging. In addition to their negative reputation, wading birds typically have specific requirements to breed (e.g., White et al. 2005; Parkes et al. 2012) and site selection is often unpredictable (Telfair et al. 2000). Ideally, biophilic cities would incorporate breeding habitat in areas with a lower human density where they would be unlikely to become a nuisance (e.g., away from airports and dining areas) and would be subject to lower levels of disturbance. White et al. (2005) proposed a few key points to consider when creating breeding habitat for wading birds, including proximity to areas of interest to the birds (e.g., foraging habitat, wetlands) and distance to areas with potential for conflicts (e.g., landfills, airports, aquaculture facilities). These colonies provide safe nesting habitats while simultaneously enhancing public awareness and conservation education. Additionally, they can offer opportunities for public engagement, allowing visitors to observe the colonies from a distance.

The economic value of wetlands is widely recognized, even in urban areas. Urban wetlands help in wastewater treatment, flood management, and trapping sediment, pollutants, and organic matter which enters their food chain or flows back into the estuarine ecosystem (Alongi et al. 2001; Bhanot and Chatterjee 2023). Notably, these sites can function as biodiversity hotspots, providing habitat to resident and migratory aquatic birds, including species of conservation concern (Bhanot and Chatterjee 2023). Artificially constructed wetlands offer improvements to water quality, stormwater management, and alternative habitat for wading birds and other wildlife, while also contributing to the overall aesthetics of urban spaces (Greenway and Simpson 1996). However, the successful integration of constructed wetlands into urban areas requires addressing challenges such as sedimentation, invasive species, and nutrient overloading, which can compromise their ecological and functional integrity. Regular maintenance and adaptive management are also essential to sustain these systems over time. Despite the overall economic and ecological benefits of urban wetlands, the contributions of individual wetlands are not always clear, making it difficult to advocate against development in these areas. Development of natural wetlands may rapidly turn them into a nuisance by allowing for a large proliferation of mosquitoes, which is commonly counteracted by application of insecticides, causing further damage to wetland fauna and resulting in negative perceptions towards wetland systems in general (Hutchings 2004). To help restore and maintain wetlands in urban areas, connection between wetland patches and removal of barriers surrounding wetland margins are necessary to allow the flow of nutrients and organisms and maintain ecosystem stability (Hutchings 2004). Despite these challenges, urban wetlands remain a valuable tool for enhancing urban ecosystems and promoting coexistence between anthropogenic and natural landscapes.

Urban design and infrastructure are constantly changing. For instance, we are slowly migrating towards self-driving cars, creation of walkable spaces and buildings that serve as green vertical spaces, etc. It is important to rethink how wildlife can be incorporated into these new realities as soon as they emerge to ensure the needs of wildlife are addressed in a way that promotes positive coexistence. For example, self-driving cars should be programmed to avoid both large (e.g., deer) and small (e.g., turtle) wildlife and green buildings should be carefully designed to avoid becoming a nuisance (e.g., by promoting the proliferation of mosquitos, attracting large flocks of roosting birds). The demands of urban wildlife ecology are constantly changing and with them innovative solutions to new problems are necessary.

## CONCLUSION

The presence of wading birds in urban areas underscores their adaptability and the necessity of urban habitats for supporting biodiversity as natural ecosystems decline (McKinney 2006; Pauchard et al. 2006). While their presence offers significant ecological and psychological benefits, it also brings challenges that determine their acceptance by the local public. Ultimately, public opinion is what determines if a given wildlife population will persist in an urban area or not. Thus, addressing these conflicts requires a nuanced approach that balances the ecological needs of wading birds with human expectations and urban development goals.

Effective coexistence strategies must focus on proactive urban planning and stakeholder involvement. These include designing green spaces that accommodate wading birds while minimizing conflicts, employing targeted public education plans to shift perceptions of these species, and implementing early intervention methods to prevent conflicts before they escalate. The integration of biophilic principles into urban design provides a pathway for creating cities that embrace nature while addressing the complexities of human-wildlife interactions.

Future research should continue to aim to deepen our understanding of wading bird ecology in urban environments, particularly regarding their habitat selection, adaptive behaviors, disease dynamics, and the long-term impacts of habitat fragmentation. City landcover can thus be mapped according to biophilic elements to identify strategic locations for interventions that support both wildlife and urban populations (Pedersen Zari 2023). This approach can be applied to assess wading bird habitat distribution and potential conflict areas. Additionally, city planners and policymakers should consider the evolving nature of urban spaces and incorporate innovative solutions to ensure that cities remain welcoming to both humans and wildlife. Frequent communication with the public is also important to build trust and shape opinions. As

McMahon et al. (2024) emphasized, reframing human-bird conflicts as opportunities for coexistence can be an important asset to promote coexistence while reducing direct management. In fact, early public involvement and conservation campaigns that appeal to their emotions can be notoriously successful to promote interest (Castillo-Huitrón et al. 2020; Batavia et al. 2021; McMahon et al. 2024).

Coexistence between wading birds and humans is not only achievable, but essential for sustainable urban ecosystems. Through collaborative efforts that integrate ecological, cultural, and urban planning perspectives, urban spaces can be better designed to leverage natural systems for the benefit of both humans and wildlife.

## REFERENCES

Allatson, P., & Connor, A. (2020). Ibis and the city: bogan kitsch and the avian revisualization of Sydney. *Visual Communication, 19*(3), 369–390.

Andersson, K., Davis, C. A., Blackwell, B. F., & Heinen, J. R. (2017). Wetland bird abundance and safety implications for military aircraft operations. *Wildlife Society Bulletin, 41*(3), 424–433.

Anza, I., Vidal, D., Laguna, C., Díaz-Sánchez, S., Sánchez, S., Chicote, Á., Florín, M., & Mateo, R. (2014). Eutrophication and bacterial pathogens as risk factors for avian botulism outbreaks in wetlands receiving effluents from urban wastewater treatment plants. *Applied and Environmental Microbiology, 80*(14), 4251–4259.

Arrieta, D., Tedford, S., Plocharczyk, L., & Kramer, G. (2016). Recreational activity intersects foraging Ciconiiformes at the John D. MacArthur Beach State Park. *Biodiversity, 17*(4), 149–155.

Badagliacca, P., Pomilio, F., Auricchio, B., Sperandii, A. F., Di Provvido, A., Di Ventura, M., Migliorati, G., Caudullo, M., Morelli, D., & Anniballi, F. (2018). Type C/D botulism in the waterfowl in an urban park in Italy. *Anaerobe, 54*, 72–74.

Bahnson, C. S., Hernandez, S. M., Poulson, R. L., Cooper, R. E., Curry, S. E., Ellison, T. J., Adams, H. C., Welch, C. N., & Stallknecht, D. E. (2020). Experimental infections and serology indicate that American White Ibis (*Eudocimus albus*) are competent reservoirs for type A influenza virus. *Journal of Wildlife Diseases, 56*(3), 530–537.

Barns, T. G. (1993). A survey comparison of pest control and nuisance wildlife control operators in Kentucky. *Sixth Eastern Wildlife Damage Control Conference (1993)*.

Batavia, C., Nelson, M. P., Bruskotter, J. T., Jones, M. S., Yanco, E., Ramp, D., Bekoff, M., & Wallach, A. D. (2021). Emotion as a source of moral understanding in conservation. *Conservation Biology*, *35*(5), 1380–1387.

Beatley, T. (2017). Handbook of biophilic city planning and design. In *Handbook of Biophilic City Planning and Design*.

Bhanot, C., & Chatterjee, S. (2023). Conservation of urban wetland with potential international significance: a case study on Najafgarh Jheel, Delhi, India. *International Journal of Conservation Science, 14*(3), 1057–1070.

Biophilic Cities. (2024). Partner Cities. https://www.biophiliccities.org/partner-cities. Accessed December 2024.

Bouaziz, A., Loucif, L., Ayachi, A., Guehaz, K., Bendjama, E., & Rolain, J. M. (2018). Migratory White Stork (*Ciconia ciconia*): A Potential Vector of the OXA-48-Producing *Escherichia coli* ST38 Clone in Algeria. *Microbial Drug Resistance, 24*(4), 461–468.

Brandis, K. J., Spencer, J., Wolfenden, B., & Palmer, D. (2019). Avian-botulism risk in waterbird breeding colonies and implications for environmental water management. *Marine and Freshwater Research*, *71*(2), 179–190.

Burdett, E. M., Muriel, R., Morandini, V., Kolnegari, M., & Ferrer, M. (2022). Power lines and birds: drivers of conflict-prone use of pylons by nesting White Storks (*Ciconia ciconia*). *Diversity*, *14*(11), 984.

Butler, R. W., & Vennesland, R. G. (2000). Commentary: Integrating climate change and predation risk with wading bird conservation research in North America. *Waterbirds*, *23*(3), 535–540.

Callaghan, C. J., Daneshfar, B., & Thompson, D. J. (2015). Modeling waterfowl damage to crops surrounding the Quill lakes in Saskatchewan. *Human-Wildlife Interactions, 9*(1), 87–100.

Castillo-Huitrón, N. M., Naranjo, E. J., Santos-Fita, D., & Estrada-Lugo, E. (2020). The Importance of Human Emotions for Wildlife Conservation. *Frontiers in Psychology, 11*.

Caudill, G., Wolf, D., Caudill, D., Brown, J., & Shearn-Bochsler, V. (2014). A juvenile wading-bird mortality event in urban Jacksonville, Florida, associated with the parasite Eustrongylides. *Florida Field Naturalist, 42*(3), 108–113.

Cocoves, T. C., Cook, M. I., Kline, J. L., Oberhofer, L., & Dorn, N. J. (2021). Irruptive White Ibis breeding is associated with use of freshwater crayfish in the coastal Everglades. *Ornithological Applications, 123*(1), 1–12.

Collins, R. G., & Mulley, S. J. (2005). Fool's Gold: Audubon International Certification as a Predictor of Foraging Habitat Suitability for Wading Birds, a case study. In *American Society of Landscape Architects 2005 Student Awards*.

Coluccy, J. M., Drobney, R. D., Graber, D. A., Sheriff, S. L., & Witter, D. J. (2001). Attitudes of central Missouri residents toward local giant Canada geese and management alternatives. *Wildlife Society Bulletin*, *29*, 116–123.

Coyner, D. F., Spalding, M. G., & Forrester, D. J. (2003). Influence of treated sewage on infections of *Eustrongylides ignotus* (Nematoda: Dioctophymatoidea) in eastern mosquitofish (*Gambusia holbrooki*) in an urban watershed. *Comparative Parasitology, 70*(2), 205–210.

Craig, E. C., Elbin, S. B., Danoff-Burg, J. A., & Palmer, M. I. (2012). Impacts of double-crested cormorants (*Phalacrocorax auritus*) and other colonial waterbirds on plant and arthropod communities on Islands in an urban estuary. *Waterbirds*, *35*(SUPPL. 1), 4–12.

Dayer, A. A., Rosenblatt, C., Bonter, D. N., Faulkner, H., Hall, R. J., Hochachka, W. M., Phillips, T. B., & Hawley, D. M. (2019). Observations at backyard bird feeders influence the emotions and actions of people that feed birds. *People and Nature*, *1*(2), 138–151.

Epstein, J. H., McKee, J., Shaw, P., Hicks, V., Micalizzi, G., Daszak, P., Kilpatrick, A. M., & Kaufman, G. (2006). The Australian white ibis (*Threskiornis molucca*) as a reservoir of zoonotic and livestock pathogens. *EcoHealth, 3*(4), 290–298.

Evans, B. A., & Gawlik, D. E. (2020). Urban food subsidies reduce natural food limitations and reproductive costs for a wetland bird. *Scientific Reports, 10*(1), 14021.

Fox, A. D., Elmberg, J., Tombre, I. M., & Hessel, R. (2017). Agriculture and herbivorous waterfowl: A review of the scientific basis for improved management. *Biological Reviews, 92*(2), 854–877.

Frederick, P., Gawlik, D. E., Ogden, J. C., Cook, M. I., & Lusk, M. (2009). The White Ibis and Wood Stork as indicators for restoration of the everglades ecosystem. *Ecological Indicators, 9*(6 SUPPL.).

Froneman, A. (2000). Towards the management of bird hazards on south African airports. *Proceedings of the International Bird Strike Committee IBSC25/WP-SA5, Amsterdam, Netherlands.*, 139–155.

Gohel, T., Chaudhari, T., Dodia, P., Shukla, A., & Solanki, D. (2021). Studies on nesting colonies of heronry birds in Bhavnagar City, Gujarat, India. *Indian Journal of Ecology, 48*(1), 91–97.

Grant, K. R., & Watson, J. (1995). Controlling nuisance egret and heron rookeries in Oklahoma. *Great Plains Wildlife Damage Control Workshop Proceedings, April*, 32–33.

Greenway, M., & Simpson, J. S. (1996). Artificial wetlands for wastewater treatment, water reuse and wildlife in Queensland, Australia. *Water Science and Technology, 33*(10–11), 221–229.

Guilfoyle, M. P., Fischer, R. A. (2011). Managing dredged material placement and disposal operations in relation to bird/wildlife aircraft strike hazards (BASH). *U.S. Army Engineer Research and Development Center*.

Grinde, B., & Patil, G. G. (2009). Biophilia: Does visual contact with nature impact on health and well-being? *International Journal of Environmental Research and Public Health*, *6*(9), 2332–2343.

Hattori, M. (2009). Adaptive management of urban wildlife: Resolving human-heron conflicts. University of California, Davis. MS Thesis.

Heath, J. A., & Frederick, P. C. (2005). Relationships among mercury concentrations, hormones, and nesting effort of White Ibises (*Eudocimus albus*) in the Florida Everglades. *The Auk*, *122*(1), 255–267.

Hernandez, S. M., Welch, C. N., Peters, V. E., Lipp, E. K., Curry, S., Yabsley, M. J., Sanchez, S., Presotto, A., Gerner-Smidt, P., Hise, K. B., Hammond, E., Kistler, W. M., Madden, M., Conway, A. L., Kwan, T., & Maurer, J. J. (2016). Urbanized White Ibises (*Eudocimus albus*) as carriers of *Salmonella enterica* of significance to public health and wildlife. *PLoS ONE, 11*(10).

Höfle, U., Jose Gonzalez-Lopez, J., Camacho, M. C., Solà-Ginés, M., Moreno-Mingorance, A., Manuel Hernández, J., De La Puente, J., Pineda-Pampliega, J., Aguirre, J. I., Torres-Medina, F., Ramis, A., Majó, N., Blas, J., & Migura-Garcia, L. (2020). Foraging at solid urban waste disposal sites as risk factor for cephalosporin and colistin resistant *Escherichia coli* carriage in White Storks (*Ciconia ciconia*). *Frontiers in Microbiology*, *11*, 523624.

Hosaka, T., Sugimoto, K., & Numata, S. (2017). Effects of childhood experience with nature on tolerance of urban residents toward hornets and wild boars in Japan. *PLoS ONE, 12*(4), e0175243.

Hoy, M. D. (2017). Herons and Egrets. In *Wildlife Damage Management Technical Series. 12.*

Hung, S. H., & Chang, C. Y. (2021). Health benefits of evidence-based biophilic-designed environments: A review. *Journal of People, Plants, and Environment*, *24*(1), 1–16.

Hunt, V. M. (2016). Reproductive success and habitat selection in black-crowned night-herons (*Nycticorax nycticorax*) in a city park. *American Midland Naturalist, 175*(2), 168–182.

Kidd-Weaver, A., Hepinstall-Cymerman, J., Welch, C. N., Murray, M. H., Adams, H. C., Ellison, T. J., Yabsley, M. J., & Hernandez, S. M. (2020). The movements of a recently urbanized wading bird reveal changes in season timing and length related to resource use. *PLoS ONE*, *15*(3), e0230158.

Johansson, M., Hartig, T., Frank, J., & Flykt, A. (2024). Wildlife and public perceptions of opportunities for psychological restoration in local natural settings. *People and Nature*, *6*(2), 800–817.

Lin, Y., Zhang, L., Wu, J., & Yang, K. (2023). Wild birds-the sentinel of antibiotic resistance for urban river: Study on egrets and Jinjiang river in Chengdu, China. *Environmental Research*, *216*, 114566.

Maute, K., Webb, C., Phalen, D., Martin, J., Hobson-Peters, J., Major, R. E., & French, K. (2019). Clean bill of health? Towards an understanding of health risks posed by urban ibis. *Journal of Urban Ecology*, *5*(1).

McKinney, R. A., & Raposa, K. B. (2013). Factors influencing expanded use of urban marine habitats by foraging wading birds. *Urban Ecosystems*, *16*(3), 411–426.

McKinney, M. L. (2006). Urbanization as a major cause of biotic homogenization. *Biological Conservation*, *127*(3), 247–260.

McMahon, B. J., Arroyo, B., Bunnefeld, N., Carrete, M., Daunt, F., & Young, J. C. (2024). Birds and people: from conflict to coexistence. *Ibis*, *166*(1), 23–37.

Miller, J. R. (2005). Biodiversity conservation and the extinction of experience. *Trends in Ecology and Evolution*, *20*(8), 430–434.

Mishra, N., Kalaiyarasu, S., Nagarajan, S., Rao, M. V. S., George, A., Sridevi, R., Behera, S. P., Dubey, S. C., McCracken, T., & Newman, S. H. (2012). Serological evidence of West Nile virus infection in wild migratory and resident water birds in Eastern and Northern India. *Comparative Immunology, Microbiology and Infectious Diseases*, *35*(6), 591–598.

Moreira, F., Martins, R. C., Aguilar, F. F., Canhoto, A., Martins, J., Moreira, J., & Bernardino, J. (2023). Long-term management practices successfully reduce bird-related electrical faults in a transmission grid increasingly used by white storks for nesting. *Journal of Environmental Management*, *327*, 116897.

Moreira, F., Martins, R. C., Catry, I., & D’Amico, M. (2018). Drivers of power line use by white storks: A case study of birds nesting on anthropogenic structures. *Journal of Applied Ecology*, *55*(5), 2263–2273.

Müller, T., Hlinak, A., Freuling, C., Mühle, R. U., Engelhardt, A., Globig, A., Schulze, C., Starick, E., Eggers, U., Sass, B., Wallschläger, D., Teifke, J., Harder, T., & Conraths, F. J. (2009). Virological monitoring of white storks (*Ciconia ciconia*) for avian influenza. *Avian Diseases*, *53*(4), 578–584.

Murray, M. H., Hernandez, S. M., Rozier, R. S., Kidd, A. D., Hepinstall-Cymerman, J., Curry, S. E., Yabsley, M. J., Adams, H., Ellison, T., Welch, C. N., & Lipp, E. K. (2021). Site fidelity is associated with food provisioning and *Salmonella* in an urban wading bird. *EcoHealth*, *18*(3), 345–358.

Murray, M. H., Kidd, A. D., Curry, S. E., Hepinstall-Cymerman, J., Yabsley, M. J., Adams, H. C., Ellison, T., Welch, C. N., & Hernandez, S. M. (2018). From wetland specialist to hand-fed generalist: Shifts in diet and condition with provisioning for a recently urbanized wading bird. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *373*(1745).

Nachuha, S., Ejotre, I., & Mwima, P. M. (2014). The role of Ciconiiformes in controlling pests in rice paddies of Kibimba, Eastern Uganda. *Advances in Research*, *2*(12), 797–806.

Nottingham, E. R., & Messer, T. L. (2021). A literature review of wetland treatment systems used to treat runoff mixtures containing antibiotics and pesticides from urban and agricultural landscapes. *Water (Switzerland)*, *13*(24), 3631.

Nyhus, P. J. (2016). Human-wildlife conflict and coexistence. *Annual Review of Environment and Resources*, *41*, 143–171.

Osorio, L., López-García, A., Colino-Freire, I., Ramos-Elvira, E., & Aguirre, J. I. (2024). Bird deterrent measures at a landfill decreased the productivity of a dependent population of White Stork (*Ciconia ciconia*). *Ibis*.

Parkes, M. L., Mora, M. A., & Feagin, R. A. (2012). Using scale, cover type and GIS to evaluate nuisance cattle egret colony site selection. *Waterbirds*, *35*(1), 56–63.

Parsons, K. C., Mineau, P., & Renfrew, R. B. (2010). Effects of pesticide use in rice fields on birds. *Waterbirds*, *33*(SPEC.ISSUE.1), 193–218.

Paton, P. W. C., Fellows, D. P., & Tomich, P. Q. (1986). Distribution of cattle egret roosts in Hawaiʻi with notes on the problems egrets pose to airports. *ʻElepaio*, *46*(13), 143–147.

Pauchard, A., Aguayo, M., Peña, E., & Urrutia, R. (2006). Multiple effects of urbanization on the biodiversity of developing countries: The case of a fast-growing metropolitan area (Concepción, Chile). *Biological Conservation*, *127*(3), 272–281.

Pedersen Zari, M. (2023). Understanding and designing nature experiences in cities: a framework for biophilic urbanism. *Cities and Health*, *7*(2), 201–212.

Perry, G., Boal, C., Verble, R., & Wallace, M. (2020). “Good” and “Bad” Urban Wildlife. In *Problematic Wildlife II* (pp. 141–170).

Pettigrove, V., Hassell, K., Kellar, C., Long, S., MacMahon, D., Myers, J., Nguyen, H., & Walpitagama, M. (2023). Catchment sourcing urban pesticide pollution using constructed wetlands in Melbourne, Australia. *Science of The Total Environment*, *863*, 160556.

Rihane, A., Nefla, A., Hamoumi, R. El, & Chlaida, M. (2020). The Breeding of wading Birds under anthropogenic pressure: Case of the Glossy Ibis *Plegadis falcinellus* nesting in an urban area in Morocco (Beni Yakhlef, Mohammedia). *J. Mater. Environ. Sci*, *2020*(8), 1332–1340.

Rodgers, J. A., & Schwikert, S. T. (2002). Buffer-zone distances to protect foraging and loafing waterbirds from disturbance by personal watercraft and outboard-powered boats. *Conservation Biology*, *16*(1), 216–224.

Roshnath, R., & Sinu, P. A. (2024). Using ecology-with-cities approaches to guide conservation of urban heronries in India. *Urban Ecosystems*, *27*(3), 733–740.

Roshnath, R., Athira, K., & Sinu, P. A. (2019). Does predation pressure drive heronry birds to nest in the urban landscape? *Journal of Asia-Pacific Biodiversity*, *12*(2), 311–315.

Ross, G. A. (2004). Ibis in urban Sydney: A gift from Ra or a pharaoh’s curse? *Urban Wildlife*, 148–152.

Sarlin, P. J., Morris, S., Morris, S., Morris, S., & Joseph, P. (2022). Heronries on a populous urban agglomeration and suburbs on the southwest coast of India: Nesting species and nesting trees. *Romanian Journal of Biology-Zooology*, *67*, 57–72.

Scollen, R. (2024). Urban pest or Aussie hero? Changing media representations of the Australian White Ibis. *Animals*, *14*(22), 3251.

Seixas, J. S., Hernandez, S. M., Kunkel, M. R., Weyna, A. A. W., Yabsley, M. J., Shender, L., & Nemeth, N. M. (2022). West Nile virus infections in an urban colony of American White Ibises (*Eudocimus albus*) in South Florida, USA. *Journal of Wildlife Diseases*, *58*(1), 205–210.

Seixas, J. S. (2021). Urbanization of the White Ibis (*Eudocimus albus*): Reproductive productivity and nestling West Nile virus dynamics. University of Georgia, Athens, GA.

Sharley, D. J., Sharp, S. M., Marshall, S., Jeppe, K., & Pettigrove, V. J. (2017). Linking urban land use to pollutants in constructed wetlands: Implications for stormwater and urban planning. *Landscape and Urban Planning*, *162*, 80–91.

Shriner, S. A., & Root, J. J. (2020). A review of avian influenza a virus associations in synanthropic birds. *Viruses*, *12*(11), 1209.

Singh, P., & Downs, C. T. (2016). Hadedas in the hood: Hadeda Ibis activity in suburban neighbourhoods of Pietermaritzburg, KwaZulu-Natal, South Africa. *Urban Ecosystems*, *19*(3), 1283–1293.

Soda, K., Tomioka, Y., Usui, T., Uno, Y., Nagai, Y., Ito, H., Hiono, T., Tamura, T., Okamatsu, M., Kajihara, M., Nao, N., Sakoda, Y., Takada, A., & Ito, T. (2022). Susceptibility of herons (family: Ardeidae) to clade 2.3.2.1 H5N1 subtype high pathogenicity avian influenza virus. *Avian Pathology*, *51*(2), 146–153.

Soga, M., & Gaston, K. J. (2024). Do people who experience more nature act more to protect it? A meta-analysis. *Biological Conservation*, *289*, 110417.

Telesford-Checkley, J. M., Mora, M. A., Gentry, T. J., McDonald, T. J., & Boellstorff, D. E. (2017). Impacts of heronries on water quality as evaluated through *Escherichia coli* and fecal sterol analyses. *Water Environment Research*, *89*(6), 508–518.

Telfair II, R. C., Thompson, B. C., & Tschirhart, L. (2000). Nuisance heronries in Texas: Characteristics and management. In *Texas Park & Wildlife*.

Thabethe, V., & Downs, C. T. (2018). Citizen science reveals widespread supplementary feeding of African woolly-necked storks in suburban areas of KwaZulu-Natal, South Africa. *Urban Ecosystems*, *21*(5), 965–973.

Traut, A. H., & Hostetler, M. E. (2004). Urban lakes and waterbirds: effects of shoreline development on avian distribution. *Landscape and Urban Planning*, *69*(1), 69–85.

US Department of the Interior US Fish & Wildlife Service US Department of Commerce US Census Bureau. (2016) National survey of fishing hunting and wildlife-associated recreation. https://www.fws.gov/sites/default/files/documents/2024-06/fhw2016.pdf. Accessed June 2024.

Walsh, M. G., Pattanaik, A., Vyas, N., Saxena, D., Webb, C., Sawleshwarkar, S., & Mukhopadhyay, C. (2022). A biogeographical description of the wild waterbird species associated with high-risk landscapes of Japanese encephalitis virus in India. *Transboundary and Emerging Diseases*, *69*(5), e3015–e3023.

Wang, G., Zhang, T., Li, X., Jiang, Z., Jiang, Q., Chen, Q., Tu, X., Chen, Z., Chang, J., Li, L., & Xu, B. (2014). Serological evidence of H7, H5 and H9 avian influenza virus co-infection among herons in a city park in Jiangxi, China. *Scientific Reports*, *4*(1), 1–6.

Watts, B., & Watts, M. (2018). Assessing the status and distribution of nesting herons in urban areas of lower Tidewater, Virginia (2018 breeding season). In *The Center for Conservation Biology Technical Report Series, CCBTR-18-11*. College of William and Mary & Virginia Commonwealth University, Williamsburg, VA.

Weiss Reid, J. E. (2003). Public preferences for wildlife species as a focus for biodiversity conservation in Nova Scotia. Dalhousie University, Halifax, NS.

White, C. L., Frederick, P. C., Main, M. B., & Rodgers, Jr., J. A. (2005). Nesting Island Creation for Wading Birds. *EDIS*, *2005*(8).

Willis, C. S., Potvin, D. A., Cadwaladr, D., Wills, E. K., & Gilby, B. L. (2024). Landscape and habitat characteristics jointly drive the urban distribution of a nuisance species. *Urban Ecosystems*, *27*(6), 2283–2297.

Xie, Y., Zou, J., Chen, Y., Li, F., & Jiang, Q. (2024). Are wading birds the ideal focal species for broader bird conservation? A cost-effective approach to ecological network planning. *Ecological Indicators*, *160*, 111785.

## FIGURES

FIGURE 1.1. Fock of White Ibises perching on picnic tables in Jupiter, FL.

FIGURE 1.2. White Stork nest with nestling in Soto del Real, Spain.

FIGURE 1.3. An urban park in Palm Beach County, FL providing artificial habitat for wading birds while also accommodating public recreation.

# CHAPTER 2

# POST-FLEDGING MOVEMENT, HABITAT USE, AND SURVIVAL OF URBAN WHITE IBIS (*EUDOCIMUS ALBUS*) JUVENILES[1]

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## ABSTRACT

Urbanization is reshaping ecosystems globally, presenting both opportunities and challenges for wildlife, particularly during critical life stages. The post-fledging period is a vulnerable phase for birds, as juveniles navigate novel environments, acquire foraging skills, and establish movement patterns that influence survival and fitness. This study investigates the post-fledging survival, movement ecology, and habitat selection of juvenile White Ibises (*Eudocimus albus*) from urban rookeries in south Florida. Thirty fledglings were captured from two colonies: a highly urbanized rookery within a golf course community in West Palm Beach and another urban colony on a mangrove island at the St. Lucie River estuary and fitted with GPS transmitters recording locations every 15 minutes. Movement behavior was classified into two distinct patterns: resident (characterized by frequent revisitations to localized areas) and nomadic (exhibiting broader, exploratory movements) based on recursion analysis. On average, juveniles moved 11.8 ± 10.1 km from roosting to foraging locations per day and dispersed 91.7 ± 83.0 km from their natal colonies. Survival analysis using Cox proportional-hazards models indicated a 50% survival probability at approximately 130 days post-fledging, with fewer than 25% surviving beyond the first year. Habitat selection was evaluated using integrated Step-Selection Functions (iSSF), with landcover reclassified into urban (low and medium-to-high intensity), agricultural, forested wetland, non-forested wetland, and open water categories. The global and resident models revealed that juveniles selected movements characterized by frequent directional changes and habitat such as non-forested wetlands and areas with low levels of urbanization, whereas nomadic birds demonstrated conflicting associations. Overall, juveniles showed weak selections for any landcover type, suggesting inconsistent selection processes and high individual variation. Although not formally investigated, sources of mortality to urban fledglings include

anthropogenic hazards, as we detected one mortality resulting from a window collision during the first long distance foray from the natal colony. Overall, these findings highlight the complex trade-offs associated with urban adaptation and emphasize the need for holistic conservation measures overseeing both anthropogenic and natural environments for Floridian avifauna.

## INTRODUCTION

Urbanization is rapidly transforming landscapes worldwide, presenting both challenges and opportunities for wildlife. For birds, urban areas can dramatically alter resource availability, predation risk, and habitat structure, leading to shifts in behavior, and physiology (McIntyre 2014; Meillère et al. 2015; Renthlei et al. 2017). These changes may be especially pronounced during sensitive life stages, such as the post-fledging period, a time characterized by high mortality risk, increasing mobility, and the transition to independence (Whittaker and Marzluff 2009; Ausprey and Rodewald 2011; Ladin et al. 2018). Ecological pressures can be amplified in urban environments, where habitat fragmentation, altered predator communities, and novel resource distributions converge (Fischer et al. 2012; Xu et al. 2018). Urbanization often disrupts the continuity of natural habitats, forcing juveniles to navigate patchy, human-modified landscapes with limited safe corridors for movement and reduced access to high-quality foraging areas (Ladin et al. 2018; Paxton et al. 2023). Such fragmentation can increase the energetic and survival costs of movement, particularly for species reliant on specific habitat features, such as water bodies (Vangestel et al. 2010; Ellington et al. 2019; Doherty et al. 2021). At the same time, urban areas may present unexpected refuges for juveniles if predation pressures are lower or if structural habitat features, such as dense vegetation, provide sufficient cover (Ausprey and Rodewald 2011; Schmidt et al. 2024). These contrasting dynamics can lead to complex survival outcomes, where juveniles may benefit from certain urban features while simultaneously facing heightened risks due to exposure during movement between isolated habitat patches and the long-term impact to fitness is unknown (Whittaker and Marzluff 2009; Paxton et al. 2023). Because movement during the post-fledging period is critical for accessing resources, avoiding predation, and establishing future home ranges, the disruption of natural movement pathways by urban development can have profound implications for juvenile survival and, ultimately, population viability (Anders et al. 1997; Cox et al. 2014). This is particularly relevant to species that depend on social learning to establish movement routes and find foraging habitat, which may experience significant alterations in movement when exposed to highly urbanized individuals post-fledging (Bildstein 1993; Chernetsov et al. 2004; Wakefield et al. 2019). However, despite its ecological importance, post-fledging movement ecology remains underexplored in urban systems, particularly for waterbirds, a group found in urban spaces globally that often exhibit complex movement patterns that are dependent on dynamic habitats (Frederick et al. 2009; Gilbert et al. 2016; Paxton et al. 2023).

The White Ibis (*Eudocimus albus*; “ibis” hereafter) is a nomadic wading bird ubiquitous to the wetlands of the southeastern United States, where its movements have historically been shaped by the dynamic distribution of water and prey across freshwater and estuarine systems (Frederick and Ogden 1997; Herring and Gawlik 2011). Ibises feed primarily on small fish and freshwater and marine invertebrates and, as tactile feeders, depend on local hydrological fluctuations to acquire prey (Kushlan 1979; Frederick et al. 2009). Over recent decades, however, ibises shifted from using urban habitat for foraging but returning to natural wetlands for the breeding season to exploiting urban areas year-round and forming urban colonies (Dorn et al. 2011; Welch 2016; Seixas 2021). In anthropogenic environments, ibises take advantage of artificial wetlands, retention ponds, parks, and other developed green spaces (Murray et al. 2018; Murray et al. 2021). This shift toward urban habitat use is facilitated by the species' ability to exploit novel resources, including provisioned food from humans, which may help explain differences in movement patterns of urban ibises (Murray et al. 2018). GPS-tracking of adult urban ibises revealed that birds with higher use of urban habitat showed high foraging site fidelity to urban locations such as parks and zoos, moved less within the non-breeding season and undertook earlier, and shorter breeding seasons compared to natural conspecifics monitored during the same period (Kidd 2018; Murray et al. 2021). Urban habitats not only provide predictable foraging opportunities but also support communal roosts and nesting colonies, suggesting that some urban areas may now offer the resources necessary to support multiple stages of the ibis life cycle (Hernandez et al. 2016; Murray et al. 2020).

Ibises have demonstrated the capacity to successfully breed in urban environments, with some urban colonies in South Florida producing fledglings at rates comparable to or even exceeding those of natural wetland rookeries (Seixas 2021). This reproductive success in developed landscapes has been attributed to several factors, including the reliability of anthropogenic food resources and reduced predation pressure. Similar patterns have been documented in other urban-adapted wading birds, such as Wood Storks (*Mycteria americana*), White Storks (*Ciconia ciconia*), and Australian White Ibises (*Threskiornis molucca*), which have established thriving colonies in city parks and suburban neighborhoods where consistent resources and lower environmental variability may promote reproductive output (Corben and Munro 2006; Massemin-Challet et al. 2006; Djerdali et al. 2016). Ibises nest in multi- or single-species colonies on tree islands surrounded by water and alligators, which tend to exclude predators (Frederick and Collopy 1989; Nell et al. 2016; Burtner and Frederick 2017). Thus, despite these advantages, only a small number of urban ibis rookeries have been documented in south Florida, potentially driven by the specific requirements of ibises to breed (Welch 2016). The long-term implications of these urban colonies depend in part on the survival and movement patterns of the juveniles they produce. If young ibises dispersing from urban rookeries remain within or near developed areas, they may facilitate the establishment of additional urban colonies and contribute to sustained growth of the urban ibis population. As ibises tend to follow adult conspecifics to foraging and breeding sites due to their inexperience, we expected urban juveniles to join highly urbanized flocks and remain in urban environments (Petit and Bildstein 1987; Bildstein 1993; Smith 1995).

This study aimed to characterize the post-fledging survival, movement ecology, and habitat selection of juvenile ibises raised in urban environments. To address this objective, we tracked GPS-marked fledglings originating from urban rookeries to assess their spatial movements and habitat use during the critical early months of independence. Beyond its applied relevance to population growth and management, this work also contributes to broader questions in movement ecology by examining how urbanization shapes the behavior of a species with inherently nomadic tendencies and complex, resource-driven movement patterns (Kushlan 1981; Frederick et al. 2009). Ibises are a particularly informative model because they combine high mobility with a demonstrated capacity to exploit urban landscapes. Understanding how juveniles from urban colonies navigate these environments provides valuable insights into how urbanization alters the development of movement strategies in birds, which may have effects lasting into adulthood. Highly urbanized adult ibises already exhibit significant shifts in movement patterns and habitat use and such impacts on movement ecology could be intensified in birds exposed to both the urban ecosystem and highly urbanized conspecifics soon after hatching (Kidd-Weaver et al. 2020).

## METHODS

### *Study Sites*

We visited two urban ibis colonies (Fig. 2.1) in south Florida from May to July 2022–2024. One rookery (“inland” colony hereafter) was located within a golf course community in West Palm Beach (26.825079, -80.149621), which was readily accessible to researchers, and composed of three small adjacent islands that collectively accounted for approximately 2,000 $m^2$ in area. The site is known to attract hundreds of breeding water birds including Great Egrets (*Ardea alba*), Great Blue Herons (*Ardea herodias*), Little Blue Herons (*Egretta caerulea*), Tricolored Herons (*Egretta tricolor*), Black-crowned Night Herons (*Nycticorax nycticorax*), and Egyptian Geese (*Alopochen aegyptiaca*). Ibises and Great Egrets are the two most abundant species nesting at this location, both with nesting pairs reaching between 100 and 200 annually. The other colony (“coastal” colony hereafter) is located in a mangrove island at the St. Lucie River estuary in Martin County (27.174546, -80.175489) and is approximately 3,000 $m^2$ in area. Nesting species include primarily ibises (over 500 breeding pairs), but also a few pairs of Great Egrets, Little Blue Herons, Tricolored Herons, and Black-crowned Night Herons.

### *Fledgling Captures and GPS Tracking*

A total of 30 ibises were captured by hand at the inland ($n = 21$) and coastal ($n = 9$) rookeries. From each fledgling, morphometric measurements (culmen length, tarsus length and width, and wing chord) and weight were recorded. Age was determined based on feather coloration and bill morphology (Bildstein 1993). Fledglings were fitted with solar-powered OrniTrack-15 (4G) GPS transmitters (Ornitela, UAB, Vilnius, Lithuania) using a backpack harness composed of a Teflon ribbon tape (Bally Ribbon Mills, Bally, PA, USA) attached to the bird using a figure-8 fit. The harness was secured by tying the ends of the ribbon tape at sternum-height, sewing the knots, and applying non-toxic glue at the ends to prevent fraying (Fig. 2.2). The tape used for the harness had some flexibility to accommodate growth, but we also ensured that the fit was not too tight to produce discomfort and not too loose to move out of place or let a wing pass through. Transmitters were only deployed on fledglings if the combined weight of the transmitter and harness did not exceed 3% of the bird's body mass (Casper 2009). Tracked fledglings ranged from 16–26 days in age and 560-880 g at the time of capture. GPS units reported locations in 15-minute intervals every 24 hours. Transmissions were monitored until February 2025 or until transmitter failure was registered, yielding between 28–25,936 (median = 4,426) locations per bird over 2–590 (median = 139) days. All capture and handling procedures were approved by the University of Georgia's Institutional Animal Care and Use Committee (AUP #A2022 08-017-Y2-A0), a Florida Wildlife Conservation Commission permit (LSSC-11-00119J), and a United States Fish and Wildlife Agency permit (MB53675D).

### *Land Cover Classification*

Land cover was categorized based on the 2023 National Land Cover Database (NLCD) map of the state of Florida and southern Georgia, which contained 20 classes at 30-m resolution (USGS 2023; https://www.mrlc.gov/data). For the purposes of this study, we reclassified the landcover into percentages of urban (low, classes: "developed, open space" and "developed, low intensity" and medium-high, classes: "developed, medium intensity" and "developed, high intensity”), agricultural (classes: “pasture/hay” and “cultivated crops”), forested wetland (class: “woody wetlands”), and non-forested wetland (class: “emergent herbaceous wetlands”) cover using a focal window with a 650-m radius. This radius was chosen based on previous studies of adult ibis habitat use using a first-time passage analysis (FPT), which revealed a median foraging radius of 650 m (Kidd-Weaver et al. 2020). As waterbirds, we expected ibises to select locations near water. To test this, we calculated distance to water by computing the Euclidean distance to the nearest open water pixel in the NLCD raster.

### *Analysis*

To analyze movement and habitat selection of ibis juveniles, we filtered the data by daylight locations. We also removed points collected when the birds were still in the colony, restricting our analysis to post-fledging movement. This process eliminated three individuals from our study, as they died at the colony and thus never left their nesting site. Additionally, one transmitter malfunctioned at deployment, never reporting any data, yielding a final sample size 26 individuals. Points from tracked individuals were reported from southern Georgia to southern Florida, therefore the entire state of Florida and southern Georgia were considered as available habitat to account for ibises’ nomadic behavior and common long-distance dispersal patterns (Frederick et al. 1996). When looking at resource selection, we used a 200 m buffer around each location to account for transmitter inaccuracy and potential outliers (Clements et al. 2021). Ibises frequently shift between nomadic and resident movement patterns in response to resource availability and habitat conditions (Frederick et al. 1996; Kidd-Weaver et al. 2020). To identify and quantify these behavioral states, we classified GPS locations as either “nomadic” or “resident” based on recursion analyses, which measured revisitation rates. A location was considered part of a resident behavior event if an individual revisited the same 6-km radius area more than five times; locations with fewer than five revisits were classified as nomadic. We selected a 6-km radius threshold based on visual inspection of movement tracks after experimenting with multiple radii, as it captured the scale at which individuals appeared to transition between localized residency and broader, exploratory movements.

To evaluate how these behavioral states influenced post-fledging movement and habitat selection, we modeled step-level movement decisions using integrated Step-Selection Functions (iSSF; Signer et al. 2024). We constructed separate models for the full dataset (“global”), as well as for subsets of the data representing only nomadic or only resident behaviors. Model predictor variables included step length, turning angle, distance to water bodies, and the proportion of landcover types encountered along each buffered step, categorized as forested wetlands, non-forested wetlands, low urban, medium-to-high urban, and agricultural areas.

Post-fledging survival was analyzed using Cox proportional-hazards models (Cox 1972). Models included a baseline model, a model using colony of origin as the independent variable, and a second using movement strategy (i.e., nomadic or resident). The latter involved computing the ratio of time spent moving in resident over nomadic patterns to determine which movement strategy each juvenile employed most. Birds with mortalities occurring within the first 30 days post-fledging were removed from the movement strategy survival model as less than 30 days does not provide sufficient time for birds to exhibit significant resident movement patterns. All analyses were conducted in R version 4.3.3, using the recurse package to calculate revisitation metrics, the amt package to build and fit iSSF models, and survival to compute survival models.

## RESULTS

We GPS-tracked 26 urban ibis juveniles and grouped them based on how they moved for most of their time: being categorized as “nomadic” if they moved predominantly following nomadic patterns and “resident” if they tended to revisit locations regularly. Seven juveniles died within their first month after leaving the colony and therefore their predominant movement behavior could not be determined. Of the individuals with sufficient movement data for classification, 14 were classified as resident and five as nomadic. Resident individuals maintained localized movements, frequently revisiting the same areas over time, while nomadic individuals engaged in broader, less predictable movements across the landscape. Movement behavior did not appear to correspond directly with colony origin, though sample sizes were too small to formally assess these differences. Ibises moved on average 11.8 ± 10.1 (SD) km per day and dispersed on average 91.7 ± 83.0 km away from the natal rookery. Figure 2.3 illustrates the different movement strategies employed by fledglings, including an example of one individual displaying long-distance dispersal and another remaining near the nesting site. Dispersal was measured by computing the distance between the first (at colony) and last point locations.

We assessed post-fledging survival across the first and second year of independence. All survival metrics reported herein are of apparent survival as transmitter malfunction could have occurred and mortalities were not confirmed. Overall survival probability declined steadily over time, with an estimated 50% ± 0.20 (SE) survival probability at approximately 130 days post-fledging and fewer than 25% ± 0.44 of individuals survived beyond year 1 (Fig. 2.4). The highest rates of mortality occurred within the first 100 days. Although differences in survival were observed across colony types and movement strategies, these effects were not statistically significant. Survival probability was lower for birds from the coastal colony compared to the inland (Fig. 2.4), but this was not significant (n = 26, $\chi^2$ = 0.185, df = 1, $P$ = 0.72). Most mortalities among coastal colony juveniles occurred within the first 50 days post-fledging, after which survival stabilized, while birds from the inland site exhibited a more gradual decline in survival across the tracking period. Similarly, survival varied between individuals exhibiting resident and nomadic movement strategies (Fig. 2.4). Birds classified as nomadic experienced earlier and steeper declines in survival, whereas resident individuals showed higher survival across the study period. However, this trend also was not significant in the Cox model (n = 19, $\chi^2$ = 1.05, df = 1, $P$ = 0.12), suggesting no strong statistical support for differences in mortality risk between movement strategies. These findings warrant cautious interpretation, particularly given the limited sample size and the small number of individuals tracked from the coastal colony. We also ran survival models using fledgling weight, age, and body condition (i.e., tarsus length/weight; Murray et al. 2018) at the time of capture as covariates to determine if fledglings caught when they were older and larger were more likely to survive, possibly due to fewer and milder potential detrimental impacts from transmitters (as older individuals were closer to mature weight and size) and lower transmitter + harness to body weight ratio. The models failed to detect significant differences in survival ($P > 0.10$).

Ibises exhibited distinct patterns of habitat selection across all movement behaviors, with differences in selection strength and direction depending on behavioral status (Fig. 2.5). Step length, forested wetland, and distance to water were not significant covariates in any model ($P >$ 0.05). However, their selection pattern was constant in every model, with birds moving with shorter step lengths, and selecting for areas near water but avoiding forested wetlands (except in the resident model). Overall, selection strengths were very weak for each of the habitat features analyzed. In the global model, which included all movement data (i.e., both resident and nomadic points), juvenile ibises selected for movement with frequent directional changes (-0.78, 95% CI = -0.79 – -0.77, *P* < 0.001), and habitat, most notably non-forested wetlands (0.024, 95% CI = 0.017–0.03, *P* < 0.001) and areas of low urbanization levels (0.018, 95% CI = 0.0055–0.030, *P* = 0.004). Agricultural (-0.012, 95% CI = -0.026– 0.0018, *P* = 0.09) and medium to high urbanization areas (-0.0039, 95% CI = -0.012 – 0.0047, *P* = 0.3) were not significantly selected in this model. In the resident model, individuals showed some selection for non-forested wetlands (0.030, 95% CI = 0.019–0.041, *P* < 0.001) and low urbanization areas (0.030, 95% CI = 0.012–0.049, *P* = 0.001) and medium to high urbanization areas (0.018, 95% CI = 0.0055–0.030, *P* = 0.004). Resident movement also showed frequent turning (-0.80, 95% CI = -0.81 – -0.80, *P* < 0.001), consistent with exploratory movement and foraging behavior. Agricultural (0.0049, 95% CI = -0.017– 0.027, *P* = 0.7) and medium to high urbanization areas (0.0068, 95% CI = -0.0064 – 0.020, *P* = 0.3) were not significantly selected in this model. The nomadic model revealed less consistent and contrasting habitat associations, demonstrating some selection for non-forested wetlands (0.020, 95% CI = 0.0082–0.033, *P* = 0.001), but some avoidance to agricultural (-0.023, 95% CI = -0.040 – -0.0050, *P* = 0.01) and medium to high urbanization areas (-0.014, 95% CI = -0.027 – -0.00028, *P* = 0.045). In addition to step length and medium-high urbanization environments, low urbanization areas (0.0078, 95% CI = -0.0093 – 0.025, *P* = 0.4) were also not significant in this model.

## DISCUSSION

Urban juvenile ibises showed varied dispersal patterns, with some going as far north as southern Georgia and others remaining within a few kilometers from their natal colony. In natural wetlands, adult ibises are known to travel long distances, often exceeding 60 km daily, to track the dynamic distribution of water and prey (Kushlan 1981; Frederick et al. 1996; Melvin et al. 1999). In contrast, our urban juveniles restricted their movements to an average of 11.8 ± 10.1 km/day and dispersed on average 91.7 ± 83.0 km away from their natal colonies by the end of the study. This is consistent with our results on adult urban ibises, which moved less and regularly returned to the same foraging areas, suggesting that most juveniles may be following urbanized flocks out of the colony as they tend to rely on following adults to find foraging habitat (Petit and Bildstein 1987; Bildstein 1993; Smith 1995; Teitelbaum et al. 2020). This reduction in dispersal distance may reflect an early-life shift toward localized movement, a pattern also observed in passerines adapting to human-altered landscapes (Whittaker and Marzluff 2009). In urban areas where resources such as artificial wetlands, landfills, retention ponds, and human-provided food in urban parks provide predictable food supplies, limited movement may confer short-term survival benefits by reducing the energetic costs and risks associated with long-distance dispersal (Dorn et al. 2011; Rogerson 2019; Doherty et al. 2021; Murray et al. 2021). Nonetheless, some ibis juveniles moved more and dispersed further, with one individual reaching 181 km from the nesting site within 5 days. Individual variation in post-fledging dispersal strategies is not uncommon in birds (Erwin et al. 1996; Bentzen and Powell 2014; Engler and Krone 2022). In ibises, this may be explained by juveniles following adults with different movement strategies but overall following flocks that traveled shorter distances (Petit and Bildstein 1987; Bildstein 1993; Smith 1995).

Main drivers of post-fledging habitat selection of waterbirds vary, with strong evidence supporting resource-driven selection, while also suggesting the influence of social learning, particularly for migratory species (Bildstein 1993; Borkhataria et al. 2012; Rotics et al. 2016; Borrmann et al. 2021). Juvenile ibises exhibited highly variable patterns of habitat use that included urban and natural environments. When in urbanized landscapes, they likely took advantage of artificial wetlands, retention ponds, and urban parks, while in natural environments, juveniles predominantly used non-forested wetlands (Fig. 2.6). These results align with previous findings showing that even highly urbanized ibises will still occasionally cross back to natural environments and suggest that, while urban environments may provide juveniles with predictable resources, these habitats may not necessarily support optimal post-fledging survival, driving juveniles to search for alternatives in natural wetlands (Teitelbaum et al. 2020). This way, urban juveniles may act as important "bridges" promoting connectivity between urban and natural ibis populations. Highly urbanized areas were not significantly selected for, or avoided by ibises, except for in the nomadic model where it was somewhat avoided, suggesting that juveniles might be hesitant to follow highly urbanized adults into these spaces and may do so less frequently.

Habitat selection for juvenile ibises was overall weak for all habitat features studied, indicating that these birds might be exploring different habitat types, with high individual variation, but generally following urbanized adults to urban areas and natural wetlands. The lack of a significant selection for areas near water may reflect the use of alternative food sources that are independent of water bodies (e.g., provisioned food) or that juveniles may be taking advantage of artificial ponds and temporary wetlands that are not reflected in the NLCD layer. The relatively inconsistent and uninformative nomadic iSSF models likely reflect the relatively indiscriminate selection process of ibises when moving following nomadic patterns. The resident model showed some selection for urban habitat with low levels of development and open wetlands, suggesting that juvenile ibises may be more likely to revisit areas that have features closely resembling their natal rookeries, which are also potential foraging spaces of parents. The inland colony, from which we captured most of the fledglings in this study, sits in a golf course community, with ample lawns and close to (~ 2 km) a natural wetland preserve. These features reflect the habitat types selected by the juveniles. Additionally, some individuals showed short dispersal distances from their natal nesting site. Evidence suggests that juvenile ibises are often hesitant to leave areas near the nesting colony and need to be encouraged by parents to initiate dispersal (Bildstein 1993). However, remaining near the natal rookery might also be associated with higher survival rates, which may subsequently translate to a selection for areas that resemble natal habitat features. In fact, localized natal site fidelity is a strategy employed by juveniles of some avian species as they transition to independence, which has been associated with increased survival (Erwin et al. 1996; Ackerman et al. 2009; Bentzen and Powell 2014; Engler and Krone 2022; Poli et al. 2024). However, while high site fidelity may provide access to known food sources, it might also limit exposure to higher-quality natural foraging areas, a trade-off that has been implicated in reduced foraging efficiency and potentially lower long-term fitness (Gutowsky et al. 2013). If urban juvenile ibises fail to engage in exploratory movements similar to those of natural conspecifics, they may experience constrained decision-making later in life. For instance, juvenile Eurasian Spoonbills (*Platalea leucorodia*) initially used a variety of habitats, but progressively specialized in fewer areas over time, reinforcing progressive habitat dependency (Rodrigues et al. 2023).

Survival during the post-fledging period is inherently low in many bird species due to inexperience, predation, and high energetic demands (Naef-Daenzer and Grüebler 2016; Lane et al. 2021; Schmidt et al. 2024). In fact, juvenile ibises are only 40% as efficient at securing prey as adults, a skill that remains underdeveloped well into their second year of life (Bildstein 1983). In our study, juvenile ibises exhibited a steady decline in survival probability over time, with the highest mortality rates occurring within the first 100 days after leaving the colony. Ibis post-fledging survival was previously estimated using band recoveries and it showed a 62% mortality rate during their first year of age (Frederick and Spalding 1994). While the survival pattern we found aligns with broader trends in juvenile avian survival, including ibises from natural rookeries, urbanization may also be introducing additional constraints on juvenile survival (Semones 2003; Ausprey and Rodewald 2011; Borkhataria et al. 2012; Ladin et al. 2018; Lane et al. 2021). Specifically, although our sample size was limited, we found that birds classified as nomadic tended to have lower survival probabilities compared to those that remained resident. These results are consistent with studies suggesting that juveniles engaging in longer or premature exploratory movements may experience higher mortality risk (Engler and Krone 2022; Poli et al. 2024). While our results were not significant, a larger sample size may eventually capture these differences in survival based on movement strategy.

Urban environments pose unique challenges to birds, which is particularly relevant to fledglings which are still learning how to navigate the landscape. For instance, one of our tracked ibises died within the first two days after fledging by colliding with a window. This was the only confirmed mortality of this study. Its transmitter was retrieved and deployed on a new fledgling the year after. However, it is possible that other mortalities due to anthropogenic influence occurred but we failed to detect them, which may raise important questions regarding the potential fitness consequences of urban habitat use during the critical post-fledging period, that may translate to an ecological trap. In fact, measured effects of urban environments on post-fledging survival are conflicting, with some studies highlighting the risks associated with common anthropogenic hazards (such as roads, buildings, and power lines) and others remarking on the importance of reliable and accessible food sources (Ausprey and Rodewald 2011; Whittaker and Marzluff 2009; Rogerson 2019). Further studies on post-fledging survival of urban ibises are necessary to determine specific causes of mortality and compare the influence of natural and anthropogenic sources.

Survival differences between ibises from different urban colonies are still not clear. Although these differences were not significant, a larger proportion of birds captured at the coastal colony died prior to fledging or within 30 days post-fledging (n = 6/9), which raises questions about what secondary factors impacting juvenile fitness be relevant at that site, including nestling diet and diseases. While we have no historical data on the coastal colony, we conducted extensive prior research at the inland site and determined that its productivity remained consistently high during two years of study and nestling diet consists of a mixture of both anthropogenic (e.g., bread) and natural (i.e., terrestrial and freshwater invertebrates) food sources, which likely is responsible for allowing them to grow at rates comparable to natural nestlings and remain in good body condition (Seixas 2021; Seixas, unpublished data). However, these nestlings were exposed to pathogens, such as *Salmonella* and West Nile virus, at higher prevalence rates (Seixas et al. 2022; Seixas et al., *under review*). Therefore, it is possible that the conditions at the coastal colony are not comparable to those of the inland site and ibis could also be under higher pressure from diseases or predation, warranting further investigation. For instance, while the coastal colony sits in an estuary and because nestling ibises are intolerant to high salt concentrations, parents heavily resort to freshwater prey to feed them (Johnston and Bildstein 1990). This imposes longer travel distances for parents at the coastal site to forage for their young and may not find optimal food sources with the same efficiency as those at the inland colony.

## CONCLUSION

Our study contributes to a growing body of evidence that urbanization can alter the movement ecology and habitat selection of waterbirds in profound ways. Juvenile ibises appear to adopt a strategy of localized movement and selective habitat use that leverages predictable urban resources. Yet, the variation in individual behavior suggests that some birds continue to bridge urban and natural environments, maintaining crucial connectivity within an increasingly fragmented landscape. The survival results reported in this study need to be interpreted with caution, given that mortalities were not confirmed (e.g., transmitter failure vs. predation). Further research is needed to address the specific risks juvenile ibises face in developed landscapes. Nonetheless, our findings underscore the complex trade-offs inherent in urban adaptation and highlight the need for integrated conservation approaches that address habitat requirements for wading birds in urban and natural environments.

## REFERENCES

Ackerman, J. T., Bluso-Demers, J. D., & Takekawa, J. Y. (2009). Postfledging Forster’s Tern movements, habitat selection, and colony attendance in San Francisco Bay. *Condor*, *111*(1), 100–110.

Anders, A. D., Dearborn, D. C., Faaborg, J., & Thompson, F. R. (1997). Juvenile survival in a population of Neotropical migrant birds. *Conservation Biology*, *11*(3), 698–707.

Ausprey, I. J., & Rodewald, A. D. (2011). Postfledging survivorship and habitat selection across a rural-to-urban landscape gradient. *Auk*, *128*(2), 293–302.

Bentzen, R. L., & Powell, A. N. (2015). Dispersal, movements and site fidelity of post-fledging King Eiders *Somateria spectabilis* and their attendant females. *Ibis*, *157*(1), 133–146.

Bildstein, K. L. (1993). White Ibis: Wetland Wanderer. Washington: Smithsonian Institution Press.

Bildstein, K. L. (1983). Age-related differences in the flocking and foraging behavior of White Ibises in a South Carolina salt marsh. *Colonial Waterbirds*, *6*, 45.

Borkhataria, R. R., Frederick, P. C., Keller, R. A., & Collazo, J. A. (2012). Temporal variation in local wetland hydrology influences postdispersal survival of juvenile Wood Storks (*Mycteria americana*). *Auk*, *129*(3), 517–528.

Borrmann, R. M., Phillips, R. A., Clay, T. A., & Garthe, S. (2021). Post-fledging migration and wintering strategies of individual juvenile Lesser Black-backed Gulls (*Larus fuscus*). *Ibis*, *163*(3), 1017–1031.

Burtner, B. F., & Frederick, P. C. (2017). Attraction of nesting wading birds to alligators (*Alligator mississippiensis*): Testing the 'nest protector' hypothesis. *Wetlands*, *37*(4), 697–704.

Casper, R. M. (2009). Guidelines for the instrumentation of wild birds and mammals. *Animal Behaviour*, *78*(6), 1477–1483.

Chernetsov, N., Berthold, P., & Querner, U. (2004). Migratory orientation of first-year white storks (*Ciconia ciconia*): Inherited information and social interactions. *Journal of Experimental Biology*, *207*(6), 937–943.

Clements, S. J., Ballard, B. M., Eccles, G. R., Sinnott, E. A., & Weegman, M. D. (2021). Trade-offs in performance of six lightweight automated tracking devices for birds. *Journal of Field Ornithology*, *92*(4), 506–517.

Cox, D. R. (1972). Regression models and life tables (with discussion). *Journal of the Royal Statistical Society: Series B*, *34*(2), 187–220

Cox, W. A., Thompson, F. R., Cox, A. S., & Faaborg, J. (2014). Post-fledging survival in passerine birds and the value of post-fledging studies to conservation. *Journal of Wildlife Management*, *78*(2), 183–193.

Doherty, T. S., Hays, G. C., & Driscoll, D. A. (2021). Human disturbance causes widespread disruption of animal movement. *Nature Ecology and Evolution*, *5*(4), 513–519.

Ellington, E. H., & Gehrt, S. D. (2019). Behavioral responses by an apex predator to urbanization. *Behavioral Ecology*, *30*(3), 821–829.

Engler, M., & Krone, O. (2022). Movement patterns of the White-tailed Sea Eagle (*Haliaeetus albicilla*): post-fledging behaviour, natal dispersal onset and the role of the natal environment. *Ibis*, *164*(1), 188–201.

Erwin, R. M., Haig, J. G., Stotts, D. B., & Hatfield, J. S. (1996). Dispersal and habitat use by post-fledging juvenile Snowy Egrets and black-crowned night-herons. *Wilson Bulletin*, *108*(2), 342–356.

Fischer, J. D., Cleeton, S. H., Lyons, T. P., & Miller, J. R. (2012). Urbanization and the predation paradox: The role of trophic dynamics in structuring vertebrate communities. *BioScience*, *62*(9), 809–818.

Frederick, P. C., Bildstein, K. L., Fleury, B., & Ogden, J. (1996). Conservation of large, nomadic populations of White Ibises (*Eudocimus albus*) in the United States. *Conservation Biology*, *10*(1), 203–216.

Frederick, P. C., & Spalding, M. G. (1994). Factors Affecting Reproductive Success of Wading Birds (Ciconiiformes) in the Everglades Ecosystem. In *Everglades* (pp. 659–691). CRC Press.

Frederick, P. C., & Collopy, M. W. (1989). The role of predation in determining reproductive success of colonially nesting wading birds in the Florida Everglades. *The Condor*, *91*(4), 860.

Frederick, P., Gawlik, D. E., Ogden, J. C., Cook, M. I., & Lusk, M. (2009). The White Ibis and Wood Stork as indicators for restoration of the everglades ecosystem. *Ecological Indicators, 9*(6).

Gilbert, N. I., Correia, R. A., Silva, J. P., Pacheco, C., Catry, I., Atkinson, P. W., Gill, J. A., & Aldina, A. M. (2015). Are white storks addicted to junk food? Impacts of landfill use on the movement and behaviour of resident white storks (*Ciconia ciconia*) from a partially migratory population. *Movement Ecology*, *4*(1).

Gutowsky, S. E., Tremblay, Y., Kappes, M. A., Flint, E. N., Klavitter, J., Laniawe, L., Costa, D. P., Naughton, M. B., Romano, M. D., & Shaffer, S. A. (2014). Divergent post-breeding distribution and habitat associations of fledgling and adult Black-footed Albatrosses *Phoebastria nigripes* in the North Pacific. *Ibis*, *156*(1), 60–72.

Hernandez, S. M., Welch, C. N., Peters, V. E., Lipp, E. K., Curry, S., Yabsley, M. J., … Maurer, J. J. (2016). Urbanized White Ibises (*Eudocimus albus*) as carriers of *Salmonella enterica* of significance to public health and wildlife. *PLoS ONE*, *11*(10).

Johnston, J. W., & Bildstein, K. L. (1990). Dietary salt as a physiological constraint in white ibis breeding in an estuary. *Physiological Zoology*, *63*(1), 190–207.

Kidd, A. D. (2018). Movement ecology of the American White Ibis (*Eudocimus albus*) across an urbanization gradient. M.S. Thesis, University of Georgia, Athens, GA.

Kidd-Weaver, A., Hepinstall-Cymerman, J., Welch, C. N., Murray, M. H., Adams, H. C., Ellison, T. J., Yabsley, M. J., & Hernandez, S. M. (2020). The movements of a recently urbanized wading bird reveal changes in season timing and length related to resource use. *PLoS ONE*, *15*(3), e0230158.

Kushlan, J. A. (1981). Resource use strategies of wading birds. *The Wilson Bulletin*, *93*(2), 145–163.

Kushlan, J. A. (1979). Feeding Ecology and Prey Selection in the White Ibis. *The Condor*, *81*(4):376.

Ladin, Z. S., Van Nieuland, S., Adalsteinsson, S. A., D'Amico, V., Bowman, J. L., Buler, J. J., Baetens, J. M., De Baets, B., & Shriver, W. G. (2018). Differential post-fledging habitat use of Nearctic-Neotropical migratory birds within an urbanized landscape. *Movement Ecology*, *6*(1).

Lane, J. V., Pollock, C. J., Jeavons, R., Sheddan, M., Furness, R. W., & Hamer, K. C. (2021). Post-fledging movements, mortality and migration of juvenile northern gannets. *Marine Ecology Progress Series*, *671*, 207–218.

Naef-Daenzer, B., & Grüebler, M. U. (2016). Post-fledging survival of altricial birds: ecological determinants and adaptation. *Journal of Field Ornithology*, *87*(3), 227–250.

Nell, L. A., Frederick, P. C., Mazzotti, F. J., Vliet, K. A., & Brandt, L. A. (2016) Presence of breeding birds improve body condition for a crocodilian nest protector. *PLoS ONE*, *11*(3).

McIntyre, N. E. (2014). Wildlife responses to urbanization: Patterns of diversity and community structure in built environments. In *Urban Wildlife Conservation: Theory and Practice* (pp. 103–115). Springer.

Meillère, A., Brischoux, F., Parenteau, C., & Angelier, F. (2015). Influence of urbanization on body size, condition, and physiology in an urban exploiter: A multi-component approach. *PLoS ONE*, *10*(8).

Melvin, S. L., Gawlik, D. E., & Scharff, T. (1999). Long-term movement patterns for seven species of wading birds. *Waterbirds*, *22*(3), 411–416.

Murray, M. H., Kidd, A. D., Curry, S. E., Hepinstall-Cymerman, J., Yabsley, M. J., Adams, H. C., … Hernandez, S. M. (2018). From wetland specialist to hand-fed generalist: Shifts in diet and condition with provisioning for a recently urbanized wading bird. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *373*(1745).

Murray, M. H., Hernandez, S. M., Rozier, R. S., Kidd, A. D., Hepinstall-Cymerman, J., Curry, S. E., … Lipp, E. K. (2021). Site fidelity is associated with food provisioning and *Salmonella* in an urban wading bird. *Ecohealth*, *18*, 345–358.

Paxton, E. H., Paxton, K. L., Kawasaki, M. T., Gorresen, P. M., van Rees, C. B., & Underwood, J. G. (2023). Hawaiian waterbird movement across a developed landscape. *Journal of Wildlife Management*, *87*(1).

Petit, D. R., & Bildstein, K. L. (1987). Effect of group size and location within the group on the foraging behavior of White Ibises. *The Condor, 89*(3), 602–609.

Poli, C. L., Meyer, K. D., Darby, P. C., Dudek, S. J., Kent, G., & Fletcher, R. J. (2024). Foray movements are common and vary with natal habitat for a highly mobile bird. *Ecology and Evolution*, *14*(3).

Renthlei, Z., Borah, B. K., & Trivedi, A. K. (2017). Effect of urbanization on daily behavior and seasonal functions in vertebrates. *Biological Rhythm Research*, *48*(5), 789–804.

Rodrigues, M. S., Araújo, P. M., Silva, J. P., Abad-Gómez, J. M., Rodrigues, P. C., Ramos, J. A., & Alves, J. A. (2023). Habitat selection and ontogeny of habitat use by juvenile Eurasian Spoonbill *Platalea leucorodia* revealed by GPS tracking. *Bird Conservation International*, *33*.

Rogerson, K. (2019). Storks on the move: the influence of anthropogenic food subsidies on the migration and movement behaviour of white storks, *Ciconia ciconia*. Ph.D. Dissertation, University of East Anglia, Norwich, England, U.K.

Rotics, S., Kaatz, M., Resheff, Y. S., Turjeman, S. F., Zurell, D., Sapir, N., Eggers, U., Flack, A., Fiedler, W., Jeltsch, F., Wikelski, M., & Nathan, R. (2016). The challenges of the first migration: movement and behaviour of juvenile vs. adult White Storks with insights regarding juvenile mortality. *Journal of Animal Ecology*, *85*(4), 938–947.

Schmidt, S. M., Benson, T. J., Osborn, J. M., & Fournier, A. M. V. (2024). Post-fledging survival and habitat use of juvenile Least Bitterns (*Ixobrychus exilis*). *Wilson Journal of Ornithology, 136*(4), 413–425.

Seixas, J. S. (2021). Urbanization of the White Ibis (*Eudocimus albus*): Reproductive productive and nestling West Nile virus dynamics. M.S. Thesis, University of Georgia, Athens, GA.

Semones, J. D. (2003). Consequences of nesting date on nesting success and juvenile survival in White Ibis. M.S. Thesis, University of Florida, Gainesville, FL.

Signer, J., Fieberg, J., Reineking, B., Schlägel, U., Smith, B., Balkenhol, N., & Avgar, T. (2024). Simulating animal space use from fitted integrated Step-Selection Functions (iSSF). *Methods in Ecology and Evolution*, *15*(1), 43–50.

Smith, J. P. (1995). Foraging sociability of nesting wading birds (Ciconiiformes) at lake Okeechobee. *The Wilson Bulletin*, *107*(3).

Teitelbaum, C. S., Hepinstall-Cymerman, J., Kidd-Weaver, A., Hernandez, S. M., Altizer, S., & Hall, R. J. (2020). Urban specialization reduces habitat connectivity by a highly mobile wading bird. *Movement Ecology, 8*(1).

Vangestel, C., Braeckman, B. P., Matheve, H., & Lens, L. (2010). Constraints on home range behaviour affect nutritional condition in urban house sparrows (*Passer domesticus*). *Biological Journal of the Linnean Society*, *101*(1), 41–50.

Wakefield, E. D., Furness, R. W., Lane, J. V., Jeglinski, J. W. E., & Pinder, S. J. (2019). Immature gannets follow adults in commuting flocks providing a potential mechanism for social learning. *Journal of Avian Biology*, *50*(10).

Welch, C. N. (2016). Urban land use and movements of White Ibises (*Eudocimus albus*) in south Florida. M.S. Thesis, University of Georgia, Athens, GA.

Whittaker, K. A., & Marzluff, J. M. (2009). Species-specific survival and relative habitat use in an urban landscape during the postfledging period. *Auk, 126*(2), 288–299.

Xu, X., Xie, Y., Qi, K., Luo, Z., & Wang, X. (2018). Detecting the response of bird communities and biodiversity to habitat loss and fragmentation due to urbanization. *Science of the Total Environment*, *624*, 1561–1576.

## FIGURES

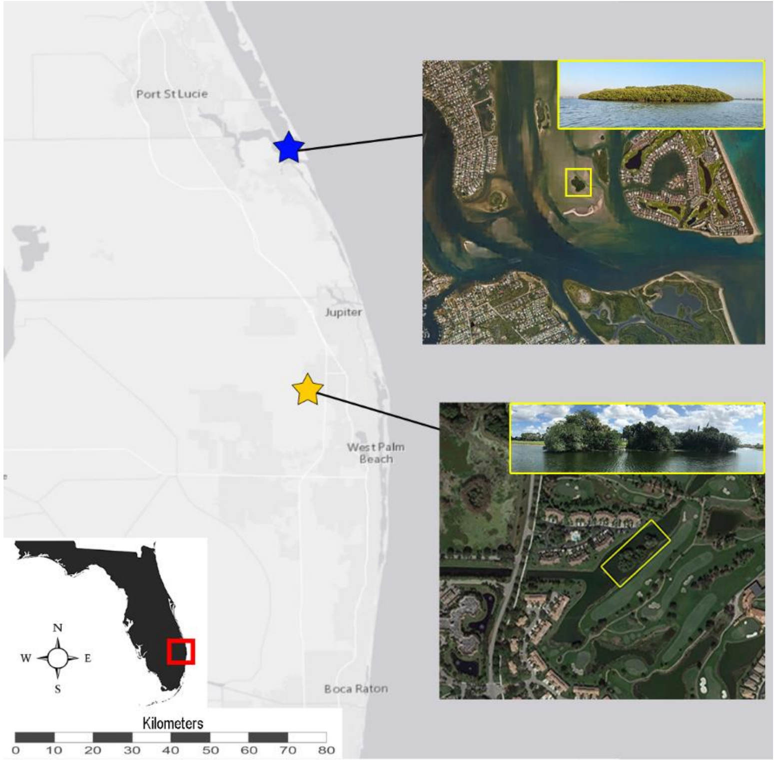

FIGURE 2.1. Two urban wading bird colonies in south Florida from which 30 White Ibis were captured and outfitted with GPS transmitters. The “coastal” colony is located at the St. Lucie

River estuary in Martin County, and it consist of a mangrove tree island (top, blue star). The “inland” colony is located inside a golf course community in Palm Beach County, and it consists of a mixed tree island, dominated by palm trees (bottom, yellow star).

FIGURE 2.2. White Ibis fledgling fit with a solar-powered GPS transmitter. We allowed some room for growth (left) by ensuring that the harness was not flush against their bodies but also not too loose that a wing could pass through. We measured fit subjectively by pulling the harness out with our fingers and ensuring that it could not move freely. We secured the ribbon tape by tying knots at the ends, sewing over the knot, and applying non-toxic glue to prevent fraying of the ends (right).

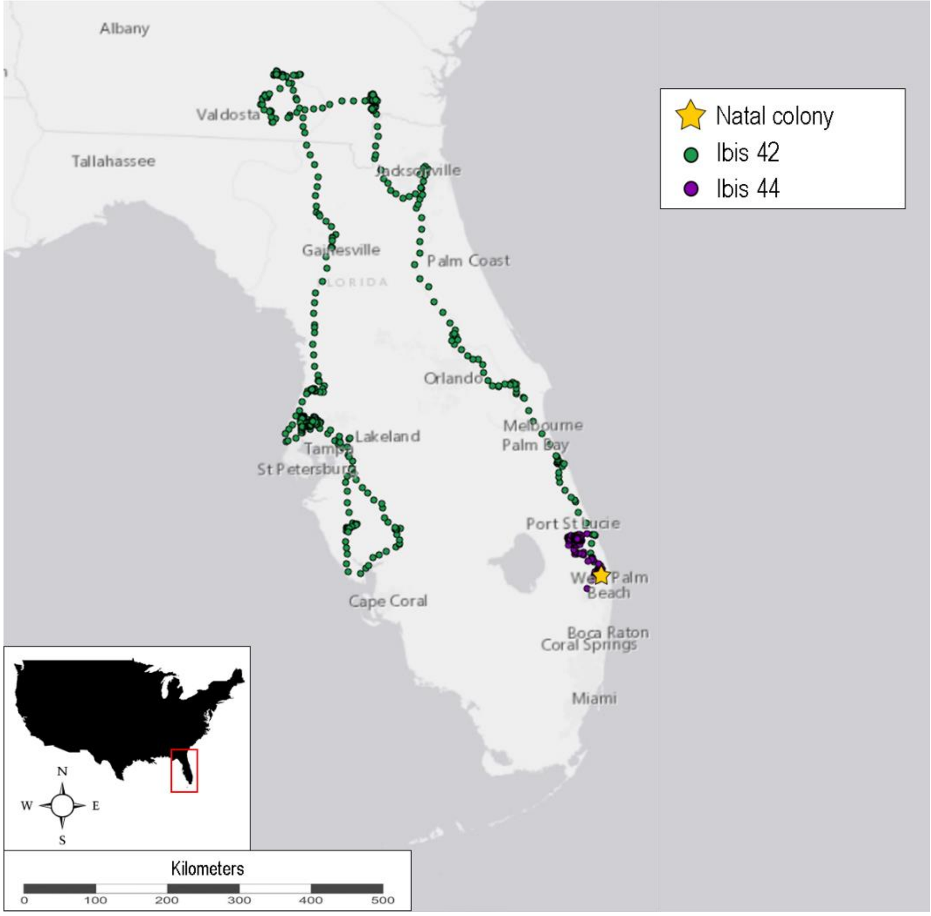

FIGURE 2.3. Map illustrating individual differences in post-fledging movement patterns of two urban White Ibises (Ibis 42 and Ibis 44) tracked via GPS from fledging until the end of the study (February 2025). Ibis 42 was captured in May 2024 and dispersed as far north as southern Georgia and traveled back south towards Tampa. Ibis 44 was captured in May 2023 and remained within a few kilometers from its natal rookery.

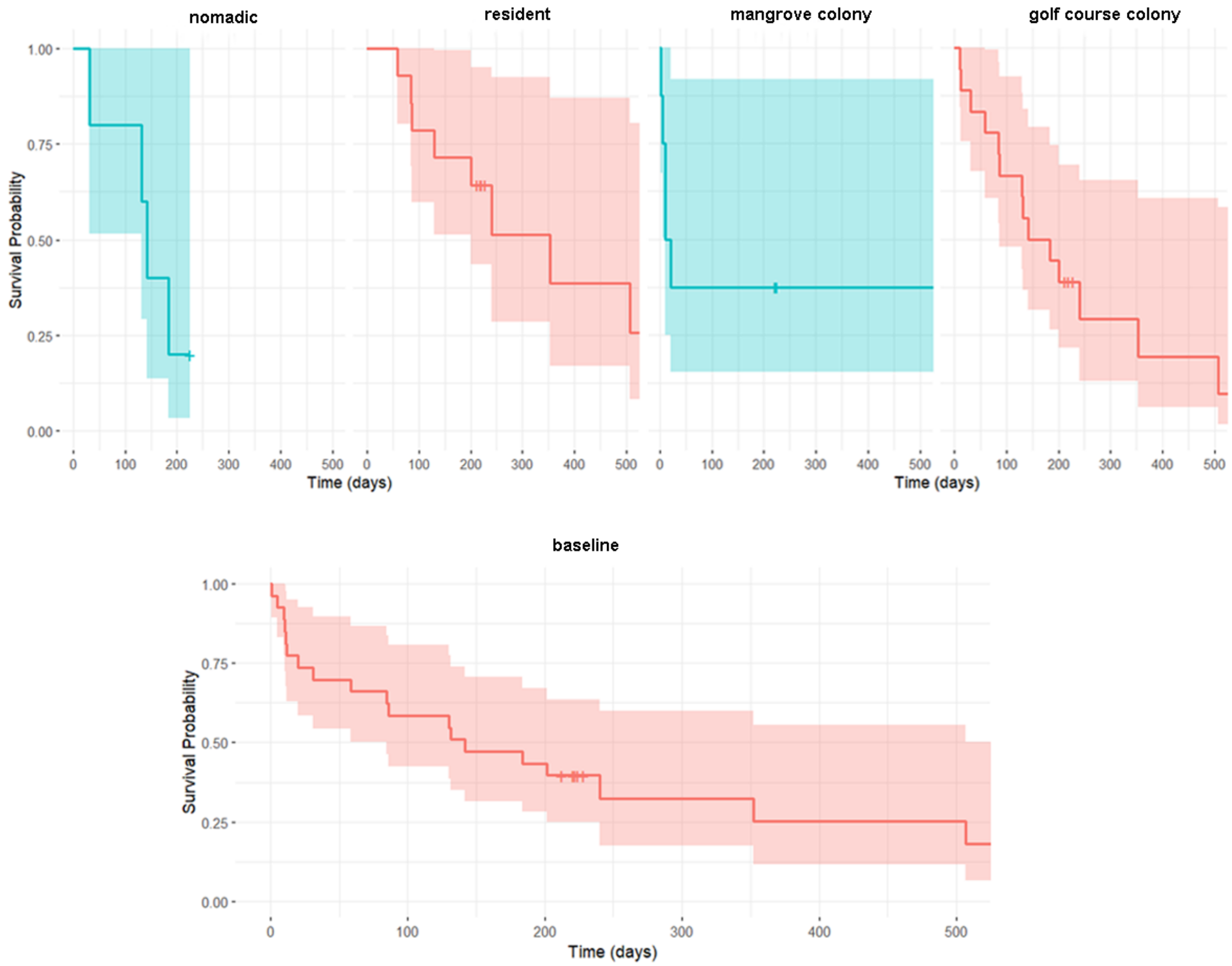

FIGURE 2.4. Post-fledging survival of White Ibis from two urban colonies (“coastal colony” and “inland colony”) in south Florida tracked via GPS from capture until February 2025 or until failure was registered. The coastal colony is located in an estuary in Martin County and the inland colony is located in a golf course community in Palm Beach County. Movement was categorized as “resident” or “nomadic” based on recursions calculated from revisitation rates to a given area. Juveniles were then divided into nomadic or resident based on their predominant movement patterns. Survival was calculated using Cox proportional-hazards models run as baseline (without grouping) and compared between ibises from different natal colonies or individuals moving based on different movement patterns. Differences in survival between colony or movement groups were not significant. Shaded areas represent standard error.

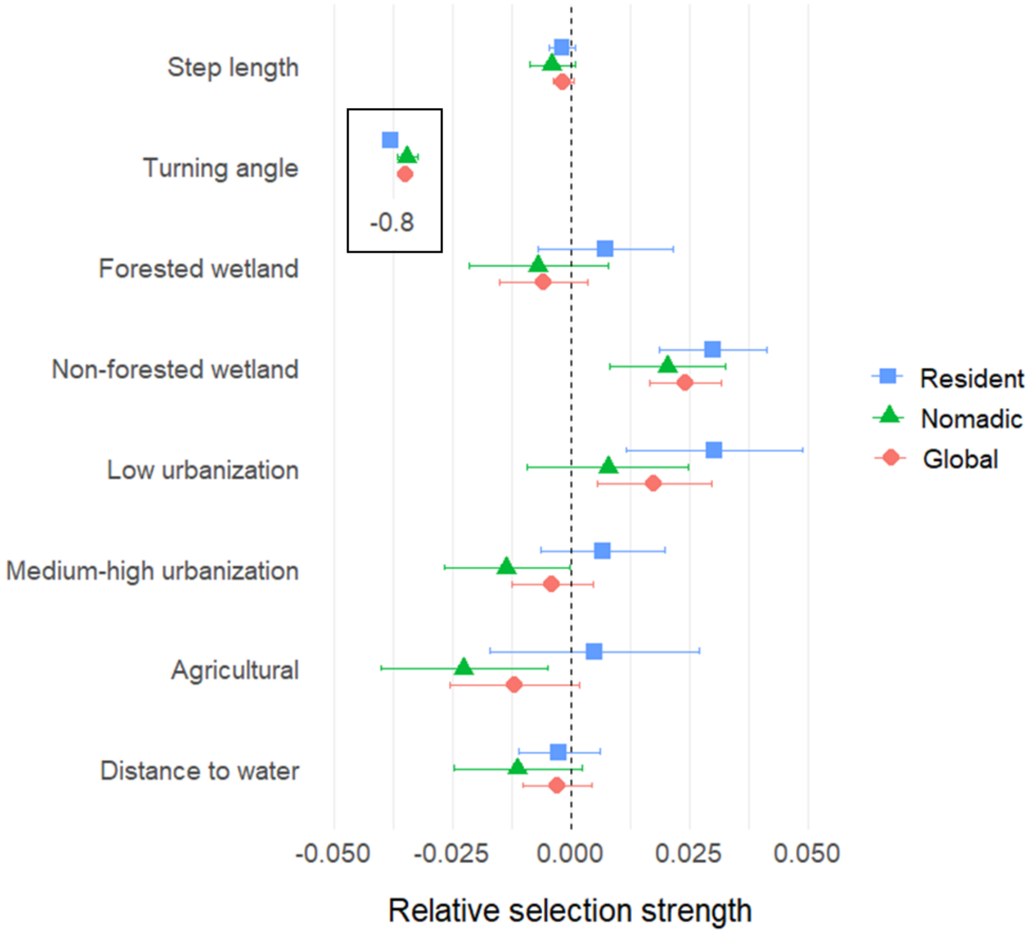

FIGURE 2.5. Results from integrated Step-Selection Function (iSSF) models analyzing post-fledging movement and habitat selection of White Ibises from two urban colonies in south Florida. Habitat variables were retrieved from the 2023 National Landcover Cover Database (NLCD) from which landcover percentages of each habitat type were calculated using focal windows. Distance to water was calculated by computing the Euclidean distance to the nearest water pixel of the NLCD raster. Bars represent 95% confidence intervals and significant results do not cross the dotted line. Selection strength for turning angle (inset box) was significantly higher in magnitude than the rest and thus it was separated to improve visibility and interpretation of the rest of the graph. Positive and negative relative selection strength values for habitat features indicate landcover that were selected for or avoided, respectively.

FIGURE 2.6. White Ibises, one adult and one juvenile (not part of this study), foraging at an artificial pond in an urban park in Palm Beach County (top, orange asterisk) and a non-forested natural wetland within Water Conservation Area 3A (bottom, green asterisk).

# CHAPTER 3

# IMPACTS OF *VIBRIO* AND *SALMONELLA* ON THE POST-FLEDGING SURVIVAL OF AN URBAN WADING BIRD AND THE ROLE OF JUVENILES IN THE TRANSMISSION PATHWAY BETWEEN URBAN AND NATURAL LANDSCAPES1

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[1] Seixas, J. S., Hernandez, S. M., Kosewick, K., Perez, K. M., Conte, D., Lipp, E. K. To be submitted to a peer-reviewed journal.

## ABSTRACT

The post-fledging period is marked by high mortality rates in birds. However, the limited existing research is focused on predation and inexperience in resource use. In this study, we investigated the impacts of waterborne pathogens, specifically *Vibrio* and *Salmonella*, on the post-fledging survival of an urban wading bird, the White Ibis (*Eudocimus albus*), in south Florida. Fledglings were hand-captured at two urban colonies (one inland and one coastal) and fitted with GPS transmitters to track their movements and resource selection. Fecal samples were collected from birds for bacterial isolation in addition to environmental samples from water bodies at their nesting sites. We confirmed the presence of multiple *Vibrio* species, including *V. cholerae* and *V. parahaemolyticus,* at a 33% prevalence across the two sites as well as *Salmonella* at 26% prevalence, including 2 coinfections. Survival analyses using Cox proportional-hazards models indicated that neither *Vibrio* nor *Salmonella* shedding significantly affected post-fledging survival and Generalized Linear Models showed that colony of origin was the only significant determinant of *Vibrio* infection status, with fledglings at the coastal rookery being more likely to shed this pathogen. These results suggest that urban ibises experience cycles of infection, clearance, and reinfection without immediate detrimental effects, with environmental exposure playing a critical role in infection. The high prevalence of these pathogens, coupled with the birds' movement between urban and natural habitats, underscores the potential for zoonotic spillover, particularly given the proximity of the study colonies to residential and public areas. We highlight the importance of continued surveillance and longer-term studies to assess potential sublethal impacts and cumulative effects on urban waterbird populations. These insights are essential for guiding conservation strategies and public health management in increasingly heterogeneous landscapes.

## INTRODUCTION

Urbanization, habitat degradation, and climate change are rapidly reshaping the dynamics of infectious diseases in wildlife. Rising global temperatures benefit important pathogens, particularly those that are water- or vector-borne, by allowing for their increased survival and transmission rates (Hofstra 2011; Gallana et al. 2013; Cohen et al. 2020). Concurrently, habitat fragmentation and altered resource distributions force wildlife into higher-density aggregations, increasing contact rates of individuals sharing common shelter and food and water sources. Such aggregations may increase the spread of pathogens transmitted through direct contact or deposition on water, soil, or food (Becker and Hall 2014; Galbraith et al. 2017). Urban wildlife, often exposed to anthropogenic stressors and forming large aggregations around common resources, are particularly vulnerable to pathogens (Becker and Hall 2014; Murray et al. 2019). Waterborne bacteria such as *Vibrio* and *Salmonella* thrive in warm urban areas where birds aggregate and accumulate organic matter (Conner et al. 2016; Siboni et al. 2016; Ayala and Ogbunugafor 2023; Oludairo et al. 2023).

The genus Vibrionaceae encompasses over 100 species, with approximately 12 of them being pathogenic to humans (Igbinosa and Okoh 2008). *Vibrio* is found in estuarine and coastal ecosystems, infecting a broad range of hosts including fish, mollusks, crustaceans, and birds (Kaspar and Tamplin 1993; Siboni et al. 2016; Ayala and Ogbunugafor 2023). In humans, *Vibrio* spp. causes a wide range of gastrointestinal symptoms and impacts over 80,000 people in the US annually (CDC 2024a). Most common routes of infection in humans include consumption of contaminated seafood and exposure of open wounds in coastal areas. *Vibrio* is not uncommon among aquatic birds such as waterfowl, shorebirds, and wading birds, which share habitat with *Vibrio,* but it can also impact nonaquatic birds (Halpern et al. 2008; Ayala and Ogbunugafor

2023). States, such as Florida, provide ample habitat for *Vibrio* spp. to thrive given its vast coastal and freshwater areas and warm water temperatures ranging from 9 to 31°C (Motes et al. 1998; Ayala et al. 2022). *Vibrio* species were previously isolated from Herring Gulls (*Larus argentatus*), Laughing Gulls (*L. atricilla*), Ring-billed Gulls (*L. delawarensis*), Brown Pelicans (*Pelecanus occidentalis*), Snowy Egrets (*Egretta thula*), and Double-crested Cormorants (*Phalacrocorax auritus*) in Florida at a prevalence of 58% across the entire study (Buck 1990). Disease and mortality have been documented in many waterbirds; however, it is unclear if pathogenic *Vibrio* species act opportunistically or as primary causative agents.

In addition to *Vibrio*, *Salmonella* is also an enteric pathogen with implications for wildlife and public health. *Salmonella* is a zoonotic bacterium, causing gastrointestinal illness and, in severe cases, systemic infections in humans, accounting for over 1.35 million cases annually in the United States (CDC 2023). Transmitted primarily via the fecal-oral route, *Salmonella* can persist in the environment (water and soil), thereby facilitating its transmission among a wide range of host species (Jensen et al. 2006; Jacobsen and Bech 2012; Liu et al. 2018). Notably, contamination from environmental sources has caused outbreaks in humans and poultry (CDC 2007; Jain et al. 2019; Patel et al. 2023). Mortalities are regularly reported in healthy passerines that aggregate at bird feeders, placing birds living in urban and suburban areas at a higher risk (Tizard 2004; Hall and Saito 2008; Lawson et al. 2018). The epidemiology of *Salmonella* and *Vibrio* in wild birds, particularly fledglings and juveniles with maturing immune systems, is of great interest given their importance to population dynamics, their increased susceptibility to disease and their inherent high mortality from other sources (Gast and Beard 1989; Roulin et al. 2007; Monticelli et al. 2008; Cox et al. 2014).

As a result of habitat deterioration and fragmentation of natural wetlands, urban areas in Florida serve as alternative habitat to multiple wading bird species, many of which also breed in small colonies in, for example, residential areas, golf courses, and zoos. One example is the White Ibis (*Eudocimus albus*, “ibis” hereafter), which has already been described to shed *Salmonella* at higher rates than those in natural areas (Hernandez et al. 2016; Seixas et al., *under review*). Ibises are nomadic wading birds that frequently cross between freshwater and marine environments when foraging and even highly urbanized ibises will still return to natural wetlands to breed (Kushlan 1979; Welch 2016). As such, they are an important species that could be transporting pathogens across multiple habitats.

Ibises typically breed in multi-species colonies located on tree islands in wetlands and coastal areas (Cocoves et al. 2021). Such colonies are characterized by large aggregations of birds, providing ample opportunities for pathogens to spread. We have previously determined that urban ibis nestlings shed *Salmonella* spp. at higher rates (81%, n = 78) than those in natural wetlands (19%, n = 36; Seixas et al., *under review*). Despite its status as a pathogen of public health relevance and of prospective increasing abundance, particularly in Florida, *Vibrio* remains understudied in urban avian populations. In this study, we investigated whether urban ibises are also impacted by *Vibrio*, more specifically, how it impacts fledglings, which are vulnerable to mortality. We were also interested in how fledglings could be acting as transporters to areas outside the colony. Although the post-fledging period is critical to ultimately determine population viability, it is also currently underexplored, particularly regarding the potential role of pathogens in juvenile survival. For this reason, we also investigated the impact of *Salmonella* and potential coinfections with *Vibrio* on fledging ibises.

## METHODS

### *Sites and captures*

We visited two urban ibis colonies in south Florida between May-July 2023 and 2024 (Fig. 3.1). One colony ("inland" colony hereafter) is located in Palm Beach County (26.825079, -80.149621) within a golf course community surrounded by a canal and less than 2 m away from a wetland preserve. This colony is composed of three small adjacent islands (ranging in area 478-1312 $m^2$), which are dominated by palm trees and shrubs. It attracts hundreds of breeding pairs of Ardeids and Phalacrocorcids every year. We have previously determined that ibises are productive in this colony, with over 70% nest success, despite higher rates of *Salmonella* shedding (Seixas 2021; Seixas et al., *under review*). The other urban colony ("coastal" colony hereafter) is in Martin County (27.174546, -80.175489) in an estuary formed by the St. Lucie River. This colony is made of a single island of mangroves, is approximately 3,000 $m^2$ in area, and it attracts primarily ibises (over 500 breeding pairs), but also a few pairs of Ardeids.

We hand captured a total of 27 ibis fledglings (n = 18 from inland colony and n = 9 from coastal) aged between 16 to 26 days, recorded their morphometric measurements (i.e., culmen length, tarsus length, tarsus width, and wing chord), weight, and body condition, and collected fecal samples. Age was determined based on feather coloration and bill morphology (Bildstein 1993). Body condition was calculated by subjectively scoring pectoral muscle mass from 1 (emaciated) to 5 (obese) and as the ratio between tarsus length (measurement that most strongly correlated to mass) and weight (Murray et al. 2018). Birds usually defecated upon handling, but a cloacal swab with a sterile cotton applicator was used as an alternative when necessary. As part of another study on urban juvenile movement and resource selection, these fledglings were also fitted with a solar powered GPS-transmitter (OrniTrack-15 (4G); Ornitela, UAB, Vilnius, Lithuania), not exceeding 3% of the birds' body mass (Casper 2009). Locations were recorded every 15 min for up to 21 months or until failure was registered. All animal care procedures were approved by the University of Georgia Institutional Animal Care and Use Committee (AUP #A2022 08-017-Y2-A0). This study was approved by a Florida Fish and Wildlife Conservation Commission permit (LSSC-11-00119J) and a US Fish and Wildlife Service permit (MB53675D).

### *Vibrio and Salmonella isolation*

For *Vibrio* isolation, 1 g of feces was enriched in 10 mL of Alkaline Peptone Water (APW) and kept at room temperature until it was shipped to the University of Georgia Department of Environmental Health for analysis within one day of collection. Samples were then inoculated on Thiosulfate citrate bile salts sucrose agar (TCBS) and streaked for colony isolation. Isolates morphologically consistent with *Vibrio* were stored in 1% salt Luri-Bertani (1% LBS) agar stabs and frozen at –80 ºC in freezer stocks containing 20% glycerol by volume at final concentration. Cultured isolates were confirmed by a *Vibrio*-specific 16S rRNA qPCR assay (Tonon et al. 2017). Any isolates that tested negative or had abnormal melt peaks (< 79 ºC or > 81 ºC) were removed. To decrease the probability of non-target species being amplified by our assay, 15 fledgling isolates with Cq values ≤ 26 and 3 with Cq values > 30 were randomly selected for sequencing using the base R package (Qiu et el. 2001). Isolate selection was reviewed to ensure equal representation of different sampling events. *Salmonella* isolation was accomplished following the methods outlined by Odumeru and León-Velarde (2012) and Lee et al. (2015). Approximately 1 g of feces was embedded in 10 mL of dulcitol selenite enrichment broth and shipped to the University of Georgia Department of Environmental Health within one day of collection. A 100 µL aliquot of each sample was inoculated into Rappaport Vassiliadis broth and incubated at 43 ºC with 100 rpm. From this sample, 10 µL was streaked onto xylose lysine tergitol 4 (XLT-4) agar plates and incubated at 37 ºC overnight. Colonies morphologically consistent with *Salmonella* were tested for confirmation as outlined by Hernandez et al. (2016) by transferring them to a ChromAgar *Salmonella* Plus Agar selective media.

Samples from water bodies surrounding each colony were also collected for *Vibrio* and *Salmonella* isolations in May 2024. Water was collected from areas immediately surrounding the rookeries with a plastic collection tube, which was thoroughly washed twice with tap followed by deionized water after each use, and its contents were immediately transferred to its respective enrichment media. For pathogen isolation, water samples followed the same respective procedures outlined above with one exception: 5 mL of water was embedded into 5 mL of APW and dulcitol selenite at 2X the concentration used for fecal samples for *Vibrio* and *Salmonella* isolation respectively.

### *Vibrio DNA extraction and sequencing of isolates*

DNA Extractions were performed using the ZymoBIOMICS Mini-Prep Kit (Zymo Research Corporation, Irvine, CA, United States) on pellets of overnight 1% LBS cultures following the manufacturer's instructions. DNA concentrations were quantified using the Qubit 3.0 fluorometer (Life Technologies, Carlsbad, CA, United States) and sent for sequencing to SeqCenter (SeqCenter, Pittsburgh, PA, United States) at concentrations greater than or equal to 10 ng/µL. Illumina sequencing libraries were prepared by SeqCenter using the tagmentation-based and PCR-based Illumina DNA Prep kit and custom IDT 10 bp unique dual indices with a target insert size of 280 bp. No additional DNA fragmentation or size selection steps were performed. Illumina sequencing was performed on an Illumina NovaSeq X Plus sequencer in one or more multiplexed shared-flow-cell runs, producing 2x151 bp paired-end reads. Demultiplexing, quality control, and adapter trimming was performed with bcl-convert1 (v4.2.4).

Read quality was assessed using MultiQC (Galaxy Version 1.27+galaxy3) implemented on the Galaxy Web server (Ewels et al. 2016; The Galaxy Community 2024). Additionally, read files were trimmed of low-quality base pairs using Trimmomatic (Galaxy Version 0.39+galaxy2) on its default settings. Shovill (Galaxy Version 1.1.0+galaxy2) and SPAdes (Galaxy Version 3.15.5+galaxy2) assemblers were used for genome assembly from the trimmed short sequencing reads (Bankevich et al. 2012; Bolger et al. 2014). The resulting contigs' quality were assessed using Quast (Galaxy Version 5.3.0+galaxy0; Gurevich et al. 2013). Additionally, MLST (Galaxy Version 2.22.0) was used to scan contig FASTA files against PubMLST typing schemes to identify potential species. Finally, FastANI (Galaxy Version 1.3) was used to compare the average nucleotide identity (ANI) of isolate FASTA files to reference genomes obtained from The National Center for Biotechnology Information (NCBI) database (Jain et al. 2018; Sayers et al. 2024). Contig assemblies with greater than a 95% ANI match to reference genomes were determined to be a species match.

### *Statistical Analysis*

We assessed the effects of *Vibrio* and *Salmonella* infections on survival of juvenile ibis using Cox proportional-hazards models to examine whether infection status affected survival time (Cox 1972; R package "survival"). Survival was computed using total survival, so fledging age at the time of capture plus survival after transmitter deployment. In these models, age at capture, body condition (calculated as tarsus length/weight), and colony of origin were included as covariates; weight was excluded due to its strong correlation with age. We ran a model including *Vibrio* and *Salmonella* infections separately under the same model, as well as a combined model grouping birds that shed either pathogen, to determine if infection, regardless of pathogen, was associated with differences in survival. Additionally, we applied Generalized Linear Models (GLMs) to investigate which of these covariates best predicted the likelihood of detecting *Vibrio* or *Salmonella* in ibis fledglings. For these GLMs, we maintained the same set of covariates as in the survival models and implemented the analyses using base R functions. We used three separate GLMs: two using either *Vibrio* or *Salmonella* infection status as the dependent variable and a combined model using pathogen (*Vibrio* and/or *Salmonella*) shedding status. Each of the three models was compared to its respective null model using the Akaike Information Criterion (AIC) estimators. This combined analytical approach allowed us to comprehensively evaluate both survival outcomes and infection dynamics in relation to host and environmental factors. All analyses were conducted in R (v4.4.3).

## RESULTS

Among the 27 fledgling ibises sampled, we selected isolates from 18 fledglings for sequencing. We detected *Vibrio* in nine of these isolates (33%; n = 27), with seven being from fledglings captured at the coastal colony (n = 9; 78%) and two at the inland colony (n = 18; 11%). In addition to *Vibrio* spp., we also found *Aeromonas* spp. (*A. caviae*, n = 1; *A. enteropelogenes*, n = 2; *A. hydrophila*, n = 1), *Proteus mirabilis* (n = 2), and *Providencia hangzhouensis* (n = 1), all from samples from fledglings from the inland colony, except for one of the *P. mirabilis* isolates. Fourteen of the fledgling ibises sampled in this study (52%; n = 27) were shedding either *Vibrio*, *Salmonella*, or both (Table 3.1). One transmitter unit failed immediately after deployment, and therefore its survival is not known. Notably, all three fledglings that died before leaving the colony were shedding *Vibrio*, and two of these were captured at the inland colony. *Vibrio* species isolated from fledglings included *V. diabolicus* (n = 2), *V. parahaemolyticus* (n = 3), *V. cholerae* (n = 3), and *V. natriegens* (n = 1). *Salmonella* was detected in seven fledglings (26% prevalence), two from the coastal colony (n = 9; 22%) and five from the inland colony (n = 18; 28%), and all survived past fledging. Two juveniles, both from the coastal colony, were coinfected with both pathogens, and also survived past fledging (i.e., they left the colony). Additionally, when isolates from both environmental water samples were sequenced, *Vibrio* was detected in isolates from both urban colonies, with *V. diabolicus* being the species detected in the isolates from the two rookeries. *Salmonella* was only isolated from the water body at the coastal colony.

Most fledglings (70%, n = 23) that survived past fledging died before the end of the study. Of the surviving individuals, two were shedding *Vibrio* and two were shedding *Salmonella* (one was coinfected with both). Survival analyses revealed that neither *Salmonella* ($\chi^2$ = -0.74, df = 5, $P$ = 0.19) nor *Vibrio* ($\chi^2$ = -0.55, df = 5, $P$ = 0.28) infection status significantly affected juvenile survival (Fig. 3.2). Similarly, a combined model including birds shedding either pathogen was not significant ($\chi^2$ = -0.26, df = 4, $P$ = 0.62; Fig. 3.2). In the model evaluating *Vibrio* and *Salmonella* status separately, age ($\chi^2$ = -1.16, df = 5, $P$ = 0.077), body condition ($\chi^2$ = -0.41, df = 5, $P$ = 0.48), and natal colony ($\chi^2$ = -0.55, df = 5, $P$ = 0.46) did not significantly predict survival, and associations remained non-significant when *Vibrio* and *Salmonella* statuses were combined (age: $\chi^2$ = -0.99, df = 4, $P$ = 0.12; body condition: $\chi^2$ = -0.57, df = 4, $P$ = 0.34; natal colony: $\chi^2$ = -0.25, df = 4, $P$ = 0.68).

We build three distinct GLMs to assess potential predictors of *Vibrio* and *Salmonella* infections: two, each with one pathogen as the dependent variable and one with both combined, categorizing birds shedding either or both of the pathogens. Independent variables were consistent for all models and included colony of origin, age, and body condition scores. The GLM assessing predictors of *Vibrio* infection status indicated that colony was a significant predictor ($\beta$ = -0.64, SE = 0.17, *P* = 0.001), with juveniles from the coastal rookery being more likely to shed *Vibrio*. Neither age ($\beta$ = -0.009, SE = 1.76, *P* = 0.83) nor body condition ($\beta$ = 4.55, SE = 11.4, *P* = 0.69) significantly influenced *Vibrio* detection, however this model (AIC = 29.4) outperformed the null model (AIC = 40.0). For *Salmonella*, the GLM results revealed no significant effects of colony ($\beta$ = 0.05, SE = 0.21, *P* = 0.80), age ($\beta$ = 0.0018, SE = 0.040, *P* = 0.96), or body condition ($\beta$ = 6.27, SE = 14.3, *P* = 0.66). This model (AIC = 41.6) did not perform better than the null model for *Salmonella* (AIC = 36.1). When both pathogens were considered together in the GLM, age was not significant ($\beta$ = 0.04, SE = 1.93, *P* = 0.09), but body condition ($\beta$ = 29.8, SE = 12.4, *P* = 0.03) and colony ($\beta$ = -0.64, SE = 0.19, *P* = 0.002) were significant predictors of infection status, indicating that fledglings from the coastal colony and with higher body condition scores were more likely to be shedding either *Vibrio* or *Salmonella*. This model (AIC = 34.3) also outperformed the null model (AIC = 43.2).

## DISCUSSION

Pathogen impacts on young birds, particularly during the post-fledging period, remain poorly characterized. In colonial-nesting species, nestling mortality is rarely investigated because accessing rookeries is challenging and routine deaths from predation, starvation, or adverse weather frequently go unnoticed. Detecting an outbreak typically requires intensive, long-term surveillance to distinguish potential disease-associated mortalities from other causes. For example, in a previous study, we identified a mortality event linked to West Nile virus in nestling ibises from the inland colony after months of daily monitoring (Seixas et al. 2022). The study conducted herein reinforces the importance of continued monitoring of avian colonies due to its relevance to public and wildlife health.

Our previous work demonstrated that urban ibises, including nestlings, shed *Salmonella* at markedly higher rates than birds in natural settings (Hernandez et al. 2016; Seixas et al., *under review*). While we have not yet formally assessed *Vibrio*’s impact on adult ibis populations, preliminary data indicates that *Vibrio* is frequently detected in adult urban ibises and in water bodies within urban parks (Seixas, unpublished data). Considering the high mortality rates typically observed during the post-fledging period, we evaluated whether shedding of *Salmonella* and *Vibrio* affects post-fledging survival in urban ibises. Our study revealed that 33% (n = 27) of urban fledgling ibises shed *Vibrio* and 26% shed *Salmonella*, with coinfections detected in two individuals, all from the rookery located on the coast. Importantly, despite high mortality rates and pathogen prevalence, there were no significant differences in post-fledging survival between birds shedding *Vibrio* and/or *Salmonella* and those that were not, suggesting that these infections may not substantially compromise fledgling survival. For instance, ibises appear to experience cycles of infection, clearance, and reinfection with *Salmonella* without detectable impacts on survival (Hernandez et al. 2016; Murray et al. 2021; Seixas et al., *under review*; Seixas, unpublished data). Common sources of post-fledging mortality for ibises likely include inexperience, predation, and anthropogenic hazards such as windows and roads (Daunt et al. 2007; Naef-Daenzer and Grüebler 2016; Lane et al. 2021; Seixas, unpublished data). In fact, one of the fledglings of this study died after colliding with a window. Additional causes of mortality were not determined and thus survival results reported herein reflect apparent survival, as transmitter failure is also possible.

*Salmonella* dynamics at urban colonies appears to be consistent. In a previous study, we detected a prevalence of 28-40% (n = 18-30) in urban ibises aged 20.2 ± 2.38 days (mean ± SD; Seixas et al., *under review*) in 2020-2021, which is reflective of the age of fledglings sampled in this study (20.0 ± 3.41 days). This prevalence is similar to what we detected in this study at this same site in 2023-2024 (25-30%; n = 8-10), despite the smaller sample sizes. *Salmonella* prevalence at the coastal colony was lower (22%, n = 9, 2023 and 2024 combined), but given its very small sample size, we could not infer if this difference was meaningful. *Salmonella* shedding in ibises can be indirectly associated with their diet, as a higher consumption of anthropogenic food was positively correlated with a higher prevalence of *Salmonella* in urban ibises (adults and nestlings), and this relationship was linked to a higher foraging site fidelity to urban areas, which may be regularly contaminated with sewage and feces of *Salmonella* reservoirs frequently found at these sites (e.g., gulls, waterfowl; Rabsch et al. 2002; Tizard 2004; Palmgren et al. 2006; Murray et al. 2021; Seixas, unpublished data). Nonetheless, young nestlings (< 15 days of age) in natural wetlands were also found shedding *Salmonella* at lower, but comparable rates (19-35%, n = 36-72; Hernandez et al. 2016; Seixas et al., *under review*). Prevalence tends to be higher in younger nestlings as they are more susceptible to infection (Gast and Beard 1989; Roulin et al. 2007).

*Vibrio* shedding rates were higher in the coastal colony (78%, n = 9), aligning with evidence that environmental drivers and habitat specificity play a critical role in determining *Vibrio* abundance. Mangrove ecosystems typically exhibit high salinity, warm water temperatures, and abundant organic matter, which together create optimal conditions for the growth and persistence of *Vibrio* spp., thereby increasing the likelihood of exposure and colonization in local avian populations, particularly in young birds (Buck 1990; Kaspar and

Tamplin 1993; Motes et al. 1998; Fernández-Delgado et al. 2016; Ayala and Ogbunugafor 2023). Although the dynamics of *Vibrio* shedding in ibises has not yet been investigated, evidence from other avian species indicate that it is influenced by the transient versus persistent nature of gastrointestinal colonization. Research on waterbirds has shown that ingestion of contaminated prey can result in transient colonization, with birds shedding *Vibrio* for extended periods after a single exposure (Laviad-Shitrit et al. 2017; Laviad-Shitrit et al. 2019). This pattern implies that even brief exposures in a habitat where *Vibrio* is abundant can lead to repeated or prolonged shedding events. However, we do not know if adults or fledglings at the coastal colony consume larger amounts of marine prey and the role of diet in *Vibrio* transmission. For instance, it is not clear if *Vibrio* is transmitted directly through the consumption of contaminated marine food by fledglings or through the fecal-oral route from parents who are shedding the bacteria. Additionally, nestling ibises are intolerant to heavy salt loads and marine prey and anthropogenic food are thus used as alternative sources under suboptimal foraging conditions in freshwater habitats (Bildstein et al. 1990; Johnston and Bildstein 1990; Dorn et al. 2011). In this scenario, a diet heavy in marine prey may compromise the growing bird's immunological defense against *Vibrio*, as they have to spend more energy handling the high salt loads, facilitating colonization (Kushlan 1977; Johnston and Bildstein 1990).

The low coinfection rates with *Vibrio* (n = 2/27) might also be reflective of the different foraging strategies employed by parents in these two rookeries: while birds at the coastal colony get repeatedly exposed to *Vibrio*, they may not frequently visit urban areas where *Salmonella* is common. Conversely, ibises at the inland rookery may not visit marine environments regularly, if at all, thus limiting their exposure to *Vibrio*. As demonstrated by the water samples we collected at the two colonies studied, *Vibrio* can also be found inland, probably transported by waterbirds visiting the coast, expanding the pathogen's range and potential to infect birds that stay inland. In fact, many of the species breeding at the inland colony also exploit marine habitats, including Double-crested Cormorants (*Nannopterum auritum*) and Anhingas (*Anhinga anhinga*), thus possibly explaining the low *Vibrio* prevalence at this rookery in 2024 (20%, n = 10) and the lack of *Vibrio* isolations from this site in 2023 (n = 8). Another possible explanation for the low coinfection rates, is that *Salmonella* and *Vibrio* may experience competition within the birds' gastrointestinal system, which may lead to exclusion or aggravated virulence (Yan et al. 2023). Regardless, coinfected birds survived past fledging.

Urban ibises still cross regularly to natural wetlands, although highly urbanized individuals do so infrequently (Teitelbaum et al. 2020). Juveniles (ibises surviving past fledging) usually follow adult conspecifics after leaving the colony due their inexperience in finding foraging habitat (Petit and Bildstein 1987; Bildstein 1993). The fledglings in this study were also tracked via GPS and their movement and resource selection were analyzed as part of a related study. It revealed that, after fledging, these urban individuals showed largely indiscriminate habitat selection patterns but selected for areas of low urbanization levels and open natural wetlands, suggesting that, while many birds may initially exploit urban resources, they may also regularly connect these urban habitats with natural wetlands (Seixas, unpublished data). Additionally, we detected a large between-individual variation, showing that these birds employed unique movement strategies. This variation in movement behavior is particularly critical for understanding pathogen dynamics. Long-distance movement behavior and the degree of site fidelity directly affect the potential for pathogen dispersal and exposure (Teitelbaum et al. 2022). For instance, experimental trials with Great Cormorants (*Phalacrocorax carbo*) showed that *Vibrio* can persist in the gut for up to 72 hours post-infection (Laviad-Shitrit et al. 2017), while free-living nestling ibises have been documented to shed *Salmonella* for as long as 22 days (Seixas et al., *under review*). These shedding durations are sufficiently long so that individuals moving between urban and natural habitats may transport pathogens far from their natal colonies as ibises can travel over 60 km in a single day, facilitating the spread of these bacteria across different environments (Frederick et al. 1996).

Recent studies on migratory birds provide additional insights into these dynamics. For example, Weitzman et al. (2024) demonstrated that the physiological stresses of migration in shorebirds, rather than diet alone, might modulate microbial persistence and pathogen shedding. Additional evidence from Turjeman et al. (2020) indicates that migratory behavior can lead to distinct microbial community compositions compared to resident individuals. Such differences imply that long-distance movement exposes birds to a more heterogeneous array of pathogens, which could either be transient or, if sufficiently persistent, facilitate long-distance dispersal. Although not migratory, ibises are nomadic and capable of long-distance movement (Frederick et al. 1996). Stress in these birds is strongly associated with their ability to find food and thus shifts in their gut microbiota can be less predictable (Herring et al. 2011; Herring and Gawlik 2013). The interplay between physiological stress, gut microbiome composition, and pathogen shedding is less clear in ibises, however *Salmonella* shedding has been previously linked to a lower microbiome diversity (Murray et al. 2020).

Previous mathematical models suggested the idea that environmental transmission plays a dominant role in pathogen dynamics within the urban ibis system, indicating that environmental uptake, rather than direct contact between birds, can sufficiently sustain infection prevalence (Becker et al. 2018). This highlights the role of birds crossing between habitat types as potential introducers of new pathogens into an area. In fact, habitat specialization can mitigate pathogen spread (Teitelbaum et al. 2022). In our system, juveniles traverse both urban and natural sites and may serve as critical connectors for pathogen dispersal with important implications for pathogen dynamics. These dynamics highlight the complex interplay between individual movement strategies, environmental persistence of pathogens, and habitat specialization in shaping infection patterns.

Sequencing results intended for *Vibrio* confirmation revealed that four isolates were *Aeromonas* spp. These bacteria, particularly *A. hydrophila*, are ubiquitous in aquatic environments and have been repeatedly associated with disease outbreaks and mortality events in waterfowl (Korbel and Kösters 1989; Zbikowski et al. 2006). Several species of waterbirds, all of which are abundant in south Florida and nest with ibises in both urban and natural colonies, were proposed as reservoirs of *A. hydrophila* with the potential to spread the pathogen across landscapes (Jubirt et al. 2015; Cunningham et al. 2018). The presence of *Aeromonas* in urban ibis suggests that these birds are exposed to a wide range of waterborne pathogens. Despite the lack of evidence of disease and mortality in free-ranging ibises, urban individuals can act as important reservoirs and disseminators of multiple pathogenic bacteria.

In our study, ibises were found shedding four *Vibrio* species: *V. diabolicus* (n = 2), *V. parahaemolyticus* (n = 3), *V. cholerae* (n = 3), and *V. natriegens*, while *V. diabolicus* was isolated from water samples from both colonies. Although these species differ in their pathogenic potential based on impacts to people, several of them are of direct concern to public health. *V. parahaemolyticus* is one of the leading causes of seafood-associated gastroenteritis in the United States. *V. parahaemolyticus* infections can lead to significant morbidity, particularly in individuals with underlying health conditions (CDC 2024a). *V. cholerae*, the causative agent of cholera, is known to trigger severe, life-threatening diarrhea, dehydration, and even death in untreated cases (CDC 2024b). While most cholera cases in the United States are linked to travel or imported contaminated seafood, the isolation of *V. cholerae* from urban ibises is noteworthy. In Florida, although the number of reported *V. cholerae* cases has been low in recent years, with only five cases in 2023 (one from Palm Beach County and none in Martin County), the presence of this species in local wildlife highlights a potential risk for environmental transmission (Florida Department of Health (FDOH) 2025a). The close proximity of the ibis colonies to residential areas raises further public health concerns. The inland colony is only a few meters from residential neighborhoods, and the canal at the coastal colony is bordered by houses, with both sites experiencing recreational activities such as fishing and water sports near the coastal colony. These factors increase the exposure risk to waterborne pathogens, whether through direct contact with contaminated water or via consumption of locally caught fish and seafood.

## CONCLUSION

This study provides valuable insights into the dynamics of waterborne pathogens in urban avifauna. Although our investigation revealed that *Vibrio* and *Salmonella* infections do not significantly affect short-term post-fledging survival, their high prevalence in urban environments and the frequent crossing of avian reservoirs between different habitats highlight complex pathogen dynamics that demand an interdisciplinary approach in research and management. The detection of multiple *Vibrio* species, including those associated with severe human illnesses, alongside *Aeromonas* spp., which is linked to disease outbreaks in waterbirds, underscores the potential for zoonotic spillover, particularly given the proximity of urban colonies to residential areas and recreational water bodies. Future research should focus on long-term, longitudinal studies to assess the cumulative impacts of pathogen exposure on urban waterbird populations, including host reinfection mechanisms and comparative analyses with individuals from natural wetlands. Ibises are currently used as ecological health indicators of the Everglades ecosystem, but we also reinforce their value in public health surveillance due to their abundance in urban areas and sharing of important zoonotic pathogens (Frederick et al. 2009; Hernandez et al. 2016; Becker et al. 2018; Bahnson et al. 2020; Teitelbaum et al. 2020). Overall, while our study indicates that short-term survival is not compromised by pathogens, the long-term ecological and public health implications warrant continued investigation and proactive management strategies.

## REFERENCES

Ayala, A. J., & Ogbunugafor, C. B. (2023). When *Vibrios* take flight: A meta-analysis of pathogenic *Vibrio* species in wild and domestic birds. *Advances in Experimental Medicine and Biology, 1404*, 295–336.

Ayala, A. J., Munyenyembe, K., Almagro-Moreno, S., & Ogbunugafor, C. B. (2022). Patterns of air pressure, wind speed, and temperature are correlated with an increased risk of clinical infection from *Vibrio vulnificus* in endemic areas. *Preprint*.

Bahnson, C. S., Hernandez, S. M., Poulson, R. L., Cooper, R. E., Curry, S. E., Ellison, T. J., Adams, H. C., Welch, C. N., & Stallknecht, D. E. (2020). Experimental infections and serology indicate that American White Ibis (*Eudocimus albus*) are competent reservoirs for type A influenza virus. *Journal of Wildlife Diseases, 56*(3), 530–537.

Bankevich, A., Nurk, S., Antipov, D., Gurevich, A. A., Dvorkin, M., Kulikov, A. S., Lesin, V. M., Nikolenko, S. I., Pham, S., Prjibelski, A. D., Pyshkin, A. V., Sirotkin, A. V., Vyahhi, N., Tesler, G., Alekseyev, M. A., & Pevzner, P. A. (2012). SPAdes: A new genome assembly algorithm and its applications to single-cell sequencing. *Journal of Computational Biology, 19*(5), 455–477.

Becker, D. J., Teitelbaum, C. S., Murray, M. H., Curry, S. E., Welch, C. N., Ellison, T., Adams, H. C., Rozier, R. S., Lipp, E. K., Hernandez, S. M., Altizer, S., & Hall, R. J. (2018). Assessing the contributions of intraspecific and environmental sources of infection in urban wildlife: *Salmonella enterica* and white ibis as a case study. *Journal of the Royal Society Interface, 15*(149).

Becker, D. J., & Hall, R. J. (2014). Too much of a good thing: Resource provisioning alters infectious disease dynamics in wildlife. *Biology Letters*, *10*(7).

Bildstein, K. L. (1993). White Ibis: Wetland Wanderer. Washington: Smithsonian Institution Press.

Bildstein, K. L., Post, W., Johnston, J., & Frederick, P. (1990). Freshwater wetlands, rainfall, and the breeding ecology of White Ibises in coastal South Carolina. *The Wilson Bulletin*, *102*(1), 84–98.

Bolger, A. M., Lohse, M., & Usadel, B. (2014). Trimmomatic: A flexible trimmer for Illumina sequence data. *Bioinformatics*, *30*, 2114–2120.

Buck, J. D. (1990). Isolation of *Candida albicans* and halophilic *Vibrio* spp. from aquatic birds in Connecticut and Florida. *Applied and Environmental Microbiology*, *56*(3), 826–828.

Casper, R. M. (2009). Guidelines for the instrumentation of wild birds and mammals. *Animal Behaviour*, *78*(6), 1477–1483.

Centers for Disease Control and Prevention (CDC). (2024a). About *Vibrio* Infection. https://www.cdc.gov/vibrio/about/index.html. Accessed March 2025.

Centers for Disease Control and Prevention (CDC). (2024b). About cholera. https://www.cdc.gov/vibrio/about/index.html. Accessed March 2025.

Centers for Disease Control and Prevention (CDC). (2023). Foodborne Diseases Active Surveillance Network (FoodNet) Fast. https://www.cdc.gov/foodnetfast/. Accessed March 2025.

Centers for Disease Control and Prevention (CDC). (2007). Multistate outbreaks of *Salmonella* infections associated with raw tomatoes eaten in restaurants--United States, 2005-2006. *MMWR. Morbidity and Mortality Weekly Report*, *56*, 909–911.

Cocoves, T. C., Cook, M. I., Kline, J. L., Oberhofer, L., & Dorn, N. J. (2021). Irruptive White Ibis breeding is associated with use of freshwater crayfish in the coastal Everglades. *Ornithological Applications*, *123*(1), 1–12.

Cohen, J. M., Sauer, E. L., Santiago, O., Spencer, S., & Rohr, J. R. (2020). Divergent impacts of warming weather on wildlife disease risk across climates. *Science*, *370*(6519).

Conner, J. G., Teschler, J. K., Jones, C. J., & Yildiz, F. H. (2016). Staying alive: *Vibrio cholerae*'s cycle of environmental survival, transmission, and dissemination. In *Virulence Mechanisms of Bacterial Pathogens* (pp. 593–633).

Cox, D. R. (1972). Regression models and life tables (with discussion). *Journal of the Royal Statistical Society: Series B, 34*(2), 187–220

Cox, W. A., Thompson, F. R., Cox, A. S., & Faaborg, J. (2014). Post-fledging survival in passerine birds and the value of post-fledging studies to conservation. *Journal of Wildlife Management*, *78*(2), 183–193.

Cunningham, F. L., Jubirt, M. M., Hanson-Dorr, K. C., Ford, L., Fioranelli, P., & Hanson, L. A. (2018). Potential of double-crested cormorants (*Phalacrocorax auritus*), American white pelicans (*Pelecanus erythrorhynchos*), and wood storks (*Mycteria americana*) to transmit a hypervirulent strain of *Aeromonas hydrophila* between channel catfish culture ponds. *Journal of Wildlife Diseases*, *54*(3), 548–552.

Daunt, F., Afanasyev, V., Adam, A., Croxall, J. P., & Wanless, S. (2007). From cradle to early grave: Juvenile mortality in European shags *Phalacrocorax aristotelis* results from inadequate development of foraging proficiency. *Biology Letters, 3*(4), 371–374.

Dorn, N. J., Cook, M. I., Herring, G., Boyle, R. A., Nelson, J., & Gawlik, D. E. (2011). Aquatic prey switching and urban foraging by the White Ibis *Eudocimus albus* are determined by wetland hydrological conditions. *Ibis, 153*(2), 323–335.

Ewels, P., Magnusson, M., Lundin, S., & Käller, M. (2016). MultiQC: Summarize analysis results for multiple tools and samples in a single report. *Bioinformatics*, *32*(19), 3047–3048.

Fernández-Delgado, M., Sanz, V., Giner, S., Suárez, P., Contreras, M., Michelangeli, F., & García-Amado, M. A. (2016). Prevalence and distribution of *Vibrio* spp. in wild aquatic birds of the Southern Caribbean Sea, Venezuela, 2011–12. *Journal of Wildlife Diseases*, *52*(3), 621–626.

Florida Department of Health (FDOH). (2025a). *Vibrio vulnificus*. https://www.flhealthcharts.gov/ChartsDashboards/rdPage.aspx?rdReport=NonVitalIndNoGrpCounts.DataViewer&cid=0171. Accessed March 2025.

Florida Department of Health (FDOH). (2025b). Cholera (*Vibrio cholerae* Type O1). https://www.floridahealth.gov/diseases-and-conditions/vibrio-infections/vibrio-vulnificus/index.html. Accessed March 2025.

Frederick, P. C., Bildstein, K. L., Fleury, B., & Ogden, J. (1996). Conservation of large, nomadic populations of White Ibises (*Eudocimus albus*) in the United States. *Conservation Biology*, *10*(1), 203–216.

Frederick, P., Gawlik, D. E., Ogden, J. C., Cook, M. I., & Lusk, M. (2009). The White Ibis and Wood Stork as indicators for restoration of the everglades ecosystem. *Ecological Indicators, 9*(6).

Galbraith, J. A., Stanley, M. C., Jones, D. N., & Beggs, J. R. (2017). Experimental feeding regime influences urban bird disease dynamics. *Journal of Avian Biology*, *48*(5), 700–713.

Gallana, M., Ryser-Degiorgis, M.-P., Wahli, T., & Segner, H. (2013). Climate change and infectious diseases of wildlife: Altered interactions between pathogens, vectors and hosts. *Current Zoology*, *59*(3), 427–437.

Gast, R. K., & Beard, C. W. (1989). Age-related changes in the persistence and pathogenicity of *Salmonella typhimurium* in chicks. *Poultry Science*, *68*(11), 1454–1460.

Gurevich, A., Saveliev, V., Vyahhi, N., & Tesler, G. (2013). QUAST: Quality assessment tool for genome assemblies. *Bioinformatics*, *29*(8), 1072–1075.

Hall, A. J., & Saito, E. K. (2008). Avian wildlife mortality events due to salmonellosis in the United States, 1985-2004. *Journal of Wildlife Diseases*, *44*(3), 585–593.

Halpern, M., Senderovich, Y., & Izhaki, I. (2008). Waterfowl—The missing link in epidemic and pandemic cholera dissemination? *PLOS Pathogens*, *4*(10), e1000173.

Hernandez, S. M., Welch, C. N., Peters, V. E., Lipp, E. K., Curry, S., Yabsley, M. J., Sanchez, S., Presotto, A., Gerner-Smidt, P., Hise, K. B., Hammond, E., Kistler, W. M., Madden, M., Conway, A. L., Kwan, T., & Maurer, J. J. (2016). Urbanized White Ibises (*Eudocimus albus*) as carriers of *Salmonella enterica* of significance to public health and wildlife. *PLoS ONE*, *11*(10).

Herring, G., & Gawlik, D. E. (2013). Differential physiological responses to prey availability by the great egret and white Ibis. *Journal of Wildlife Management*, *77*(1), 58–67.

Herring, G., Cook, M. I., Gawlik, D. E., & Call, E. M. (2011). Food availability is expressed through physiological stress indicators in nestling white ibis: A food supplementation experiment. *Functional Ecology*, *25*(3), 682–690.

Hofstra, N. (2011). Quantifying the impact of climate change on enteric waterborne pathogen concentrations in surface water. *Current Opinion in Environmental Sustainability*, *3*(6), 471–479.

Igbinosa, E. O., & Okoh, A. I. (2008). Emerging *Vibrio* species: an unending threat to public health in developing countries. *Research in Microbiology*, *159*(7–8), 495–506.

Jacobsen, C. S., & Bech, T. B. (2012). Soil survival of *Salmonella* and transfer to freshwater and fresh produce. *Food Research International*, *45*, 557–566.

Jain, C., Rodriguez-R, L. M., Phillippy, A. M., Konstantinidis, K. T., & Aluru, S. (2018). High throughput ANI analysis of 90K prokaryotic genomes reveals clear species boundaries. *Nature Communications*, *9*(1).

Jain, S., Mukhopadhyay, K., & Thomassin, P. J. (2019). An economic analysis of *Salmonella* detection in fresh produce, poultry, and eggs using whole genome sequencing technology in Canada. *Food Research International*, *116*, 802–809.

Jensen, A. N., Dalsgaard, A., Stockmarr, A., Nielsen, E. M., & Baggesen, D. L. (2006). Survival and transmission of *Salmonella enterica* serovar typhimurium in an outdoor organic pig farming environment. *Applied and Environmental Microbiology*, *72*(3), 1833–1842.

Johnston, J. W., & Bildstein, K. L. (1990). Dietary salt as a physiological constraint in white ibis breeding in an estuary. *Physiological Zoology*, *63*(1), 190–207.

Jubirt, M. M., Hanson, L. A., Hanson-Dorr, K. C., Ford, L., Lemmons, S., Fioranelli, P., & Cunningham, F. L. (2015). Potential for great egrets (*Ardea alba*) to transmit a virulent strain of *Aeromonas hydrophila* among channel catfish (*Ictalurus punctatus*) culture ponds. *Journal of Wildlife Diseases*, *51*(3), 634–639.

Kaspar, C. W., & Tamplin, M. L. (1993). Effects of temperature and salinity on the survival of *Vibrio vulnificus* in seawater and shellfish. *Applied and Environmental Microbiology*, *59*(8), 2425–2429.

Kushlan, J. A. (1979). Feeding ecology and prey selection in the White Ibis. *The Condor*, *81*(4), 376.

Kushlan, J. A. (1977). Growth energetics of the White Ibis. *The Condor*, *79*(1), 31.

Lane, J. V., Pollock, C. J., Jeavons, R., Sheddan, M., Furness, R. W., & Hamer, K. C. (2021). Post-fledging movements, mortality and migration of juvenile northern gannets. *Marine Ecology Progress Series*, *671*, 207–218.

Laviad-Shitrit, S., Izhaki, I., & Halpern, M. (2019). Accumulating evidence suggests that some waterbird species are potential vectors of *Vibrio cholerae*. *PLoS Pathogens*, *15*(8).

Laviad -Shitrit, S., Lev-Ari, T., Katzir, G., Sharaby, Y., Izhaki, I., & Halpern, M. (2017). Great cormorants (*Phalacrocorax carbo*) as potential vectors for the dispersal of *Vibrio cholerae*. *Scientific Reports*, *7*(1).

Lawson, B., Petrovan, S. O., & Cunningham, A. A. (2015). Citizen science and wildlife disease surveillance. *EcoHealth*, *12*(4), 693–702.

Lee, K. M., Runyon, M., Herrman, T. J., Phillips, R., & Hsieh, J. (2015). Review of *Salmonella* detection and identification methods: Aspects of rapid emergency response and food safety. *Food Control*, *47*, 264–276.

Liu, H., Whitehouse, C. A., & Li, B. (2018). Presence and persistence of *Salmonella* in water: The impact on microbial quality of water and food safety. *Frontiers in Public Health*, *6*(159).

Monticelli, D., Ramos, J. A., Hines, J. E., Nichols, J. D., & Spendelow, J. A. (2008). Juvenile survival in a tropical population of roseate terns: Interannual variation and effect of tick parasitism. *Marine Ecology Progress Series*, *365*, 277–287.

Motes, M. L., DePaola, A., Cook, D. W., Veazey, J. E., Hunsucker, J. C., Garthright, W. E., Blodgett, R. J., & Chirtel, S. J. (1998). Influence of water temperature and salinity on *Vibrio vulnificus* in Northern Gulf and Atlantic Coast oysters (*Crassostrea virginica*). *Applied and Environmental Microbiology, 64*(4), 1459–1465.

Murray, M. H., Hernandez, S. M., Rozier, R. S., Kidd, A. D., Hepinstall-Cymerman, J., Curry, S. E., Yabsley, M. J., Adams, H., Ellison, T., Welch, C. N., & Lipp, E. K. (2021). Site fidelity is associated with food provisioning and *Salmonella* in an urban wading bird. *EcoHealth*, *18*(3), 345–358.

Murray, M. H., Lankau, E. W., Kidd, A. D., Welch, C. N., Ellison, T., Adams, H. C., Lipp, E. K., & Hernandez, S. M. (2020). Gut microbiome shifts with urbanization and potentially facilitates a zoonotic pathogen in a wading bird. *PLOS ONE*, *15*(3), e0220926.

Murray, M. H., Sánchez, C. A., Becker, D. J., Byers, K. A., Worsley-Tonks, K. E. L., & Craft, M. E. (2019). City sicker? A meta-analysis of wildlife health and urbanization. *Frontiers in Ecology and the Environment*, *17*(10), 575–583.

Murray, M. H., Kidd, A. D., Curry, S. E., Hepinstall-Cymerman, J., Yabsley, M. J., Adams, H. C., Ellison, T., Welch, C. N., & Hernandez, S. M. (2018). From wetland specialist to hand-fed generalist: Shifts in diet and condition with provisioning for a recently urbanized wading bird. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *373*(1745).

Naef-Daenzer, B., & Grüebler, M. U. (2016). Post-fledging survival of altricial birds: ecological determinants and adaptation. *Journal of Field Ornithology*, *87*(3), 227–250.

Odumeru. J. A., León-Velarde, C. G. (2012). *Salmonella* detection methods for food and food ingredients. *Salmonella*: A Dangerous Foodborne Pathogen. Rijeka, Croatia: InTech 373-392.

Oludairo, O. O., Kwaga, J. K. P., Kabir, J., Abdu, P. A., Gitanjali, A., Perrets, A., Cibin, V., Lettini, A. A., & Aiyedun, J. O. (2023). Ecology and epidemiology of *Salmonella* spp. isolated from the environment and the roles played by wild animals in their maintenance. *International Journal of One Health*, *9*(1), 1–9.

Patel, K., Stapleton, G. S., Trevejo, R. T., Tellier, W. T., Higa, J., Adams, J. K., Hernandez, S. M., Sanchez, S., Nemeth, N. M., Debess, E. E., Rogers, K. H., Mete, A., Watson, K. D., Foss, L., Low, M. S. F., Gollarza, L., & Nichols, M. (2023). Human *Salmonellosis* outbreak linked to *Salmonella Typhimurium* epidemic in wild songbirds, United States, 2020–2021. *Emerging Infectious Diseases*, *29*(11), 2298–2306.

Petit, D. R., & Bildstein, K. L. (1987). Effect of group size and location within the group on the foraging behaviour of white ibises. *Condor*, *89*(3), 602–609.

Qiu, X., Wu, L., Huang, H., McDonel, P. E., Palumbo, A. V., Tiedje, J. M., & Zhou, J. (2001). Evaluation of PCR-generated chimeras, mutations, and heteroduplexes with 16S rRNA gene-based cloning. *Applied and Environmental Microbiology*, *67*(2), 880–887.

Roulin, A., Christe, P., Dijkstra, C., Ducrest, A. L., & Jungi, T. W. (2007). Origin-related, environmental, sex, and age determinants of immunocompetence, susceptibility to ectoparasites, and disease symptoms in the barn owl. *Biological Journal of the Linnean Society*, *90*(4), 703–718.

Sayers, E. W., Beck, J., Bolton, E. E., Brister, J. R., Chan, J., Comeau, D. C., Connor, R., DiCuccio, M., Farrell, C. M., Feldgarden, M., Fine, A. M., Funk, K., Hatcher, E., Hoeppner, M., Kane, M., Kannan, S., Katz, K. S., Kelly, C., Klimke, W., … Sherry, S. T. (2024). Database resources of the National Center for Biotechnology Information. *Nucleic Acids Research*, *52*(D1), D33–D43.

Seixas, J. S., Hernandez, S. M., Kunkel, M. R., Weyna, A. A. W., Yabsley, M. J., Shender, L., & Nemeth, N. M. (2022). West Nile virus infections in an urban colony of American White Ibises (*Eudocimus albus*) in South Florida, USA. *Journal of Wildlife Diseases*, *58*(1), 205–210.

Seixas, J. S. (2021). Urbanization of the White Ibis (*Eudocimus albus*): Reproductive productive and nestling West Nile virus dynamics. M.S. Thesis, University of Georgia, Athens, GA.

Siboni, N., Balaraju, V., Carney, R., Labbate, M., & Seymour, J. R. (2016). Spatiotemporal dynamics of *Vibrio* spp. within the Sydney Harbour estuary. *Frontiers in Microbiology*, *7*(APR), 181053.

Teitelbaum, C. S., Altizer, S., & Hall, R. J. (2022). Habitat specialization by wildlife reduces pathogen spread in urbanizing landscapes. *American Naturalist*, *199*, 238–251.

Teitelbaum, C. S., Hepinstall-Cymerman, J., Kidd-Weaver, A., Hernandez, S. M., Altizer, S., & Hall, R. J. (2020). Urban specialization reduces habitat connectivity by a highly mobile wading bird. *Movement Ecology*, *8*(1).

The Galaxy Community. (2024). The Galaxy platform for accessible, reproducible, and collaborative data analyses: 2024 update. *Nucleic Acids Research*, *52*(W1), W83–W94.

Tizard, I. (2004). *Salmonellosis* in wild birds. *Seminars in Avian and Exotic Pet Medicine*, *13*(2), 50–66.

Tonon, L. A. C., Thompson, J. R., Moreira, A. P. B., Garcia, G. D., Penn, K., Lim, R., Berlinck, R. G. S., Thompson, C. C., & Thompson, F. L. (2017). Quantitative detection of active vibrios associated with white plague disease in *Mussismilia braziliensis* corals. *Frontiers in Microbiology*, *8*.

Turjeman, S., Corl, A., Wolfenden, A., Tsalyuk, M., Lublin, A., Choi, O., Kamath, P. L., Getz, W. M., Bowie, R. C. K., & Nathan, R. (2020). Migration, pathogens and the avian microbiome: A comparative study in sympatric migrants and residents. *Molecular Ecology*, *29*, 4706–4720.

Weitzman, C. L., Tinning, Z., Day, K. A., Garnett, S. T., Christian, K., & Gibb, K. (2024). Migratory Shorebird Gut Microbes are not Associated with Bivalve Prey in Monsoon Tropical Australia. *Current Microbiology*, *81*.

Welch, C. N. (2016). Urban land use and movements of White Ibises (*Eudocimus albus*) in South Florida. M.S. Thesis, University of Georgia, Athens, GA.

Yan, D., Sun, M., Xiao, L., Chen, H., Zhang, Q., Zhi, Y., & Fu, Q. (2023). Interspecies interactions of non-O1/O139 *Vibrio cholerae* and *Salmonella typhimurium*: a rare coinfection case report. *Diagnostic Microbiology and Infectious Disease, 107*(3).

Zbikowski, A., Szeleszczuk, P., Karpińska, E., Rzewuska, M., Malicka, E., & Binek, M. (2006). Epidemic deaths of mallard ducks after *Aeromonas hydrophila* infection. *Medycyna Weterynaryjna*, *62*(6).

## TABLES

TABLE 3.1. *Vibrio* and *Salmonella* prevalence from White Ibis fledglings (aged ≥ 16 days) captured at two urban colonies (one coastal and one inland) in south Florida between 2023 and 2024. Potential *Vibrio* isolates were confirmed via sequencing and species isolated are reported. The survival period was computed by adding fledging age at capture to its assumed mortality date.

| Pathogen isolated | % Prevalence (N sampled) | Colony | Species isolated | Mean survival (days ± SD)* |
|---|---|---|---|---|
| *Vibrio* | 78 (9) | Coastal | *V. cholerae*, *V. diabolicus*, *V. parahaemolyticus*, *V. natriegens* | 70 ± 8 |
| | 11 (18) | Inland | *V. cholerae*, *V. diabolicus* | 55 ± 37 |

| | | | | |
|---|---|---|---|---|
| *Salmonella* | 22 (9)[‡] | Coastal | NA | 61 ± 0 |
| | 28 (18) | Inland | NA | 348 ± 181 |

* excludes individuals still alive at the end of the study (n = 7) and one bird with a transmitter that failed at deployment, resulting in n = 19.

[‡] were coinfected with *Vibrio*.

NA: not applicable.

FIGURES

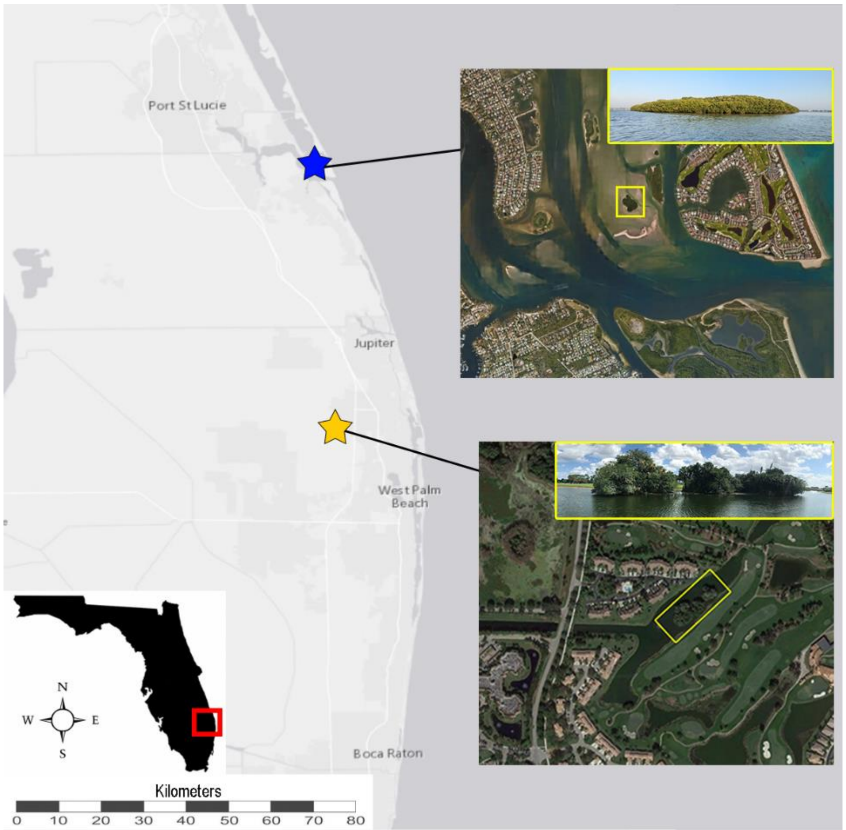

FIGURE 3.1. Two urban wading bird colonies in south Florida from which 27 White Ibis were captured, outfitted with GPS transmitters, and sampled for *Salmonella* and *Vibrio* isolation. The coastal colony (indicated by the blue star) is located at the St. Lucie River estuary in Martin County, and it consist of a mangrove tree island. The inland colony (indicated by a yellow star) is located inside a golf course community in Palm Beach County, and it consists of a mixed tree island, dominated by palm trees.

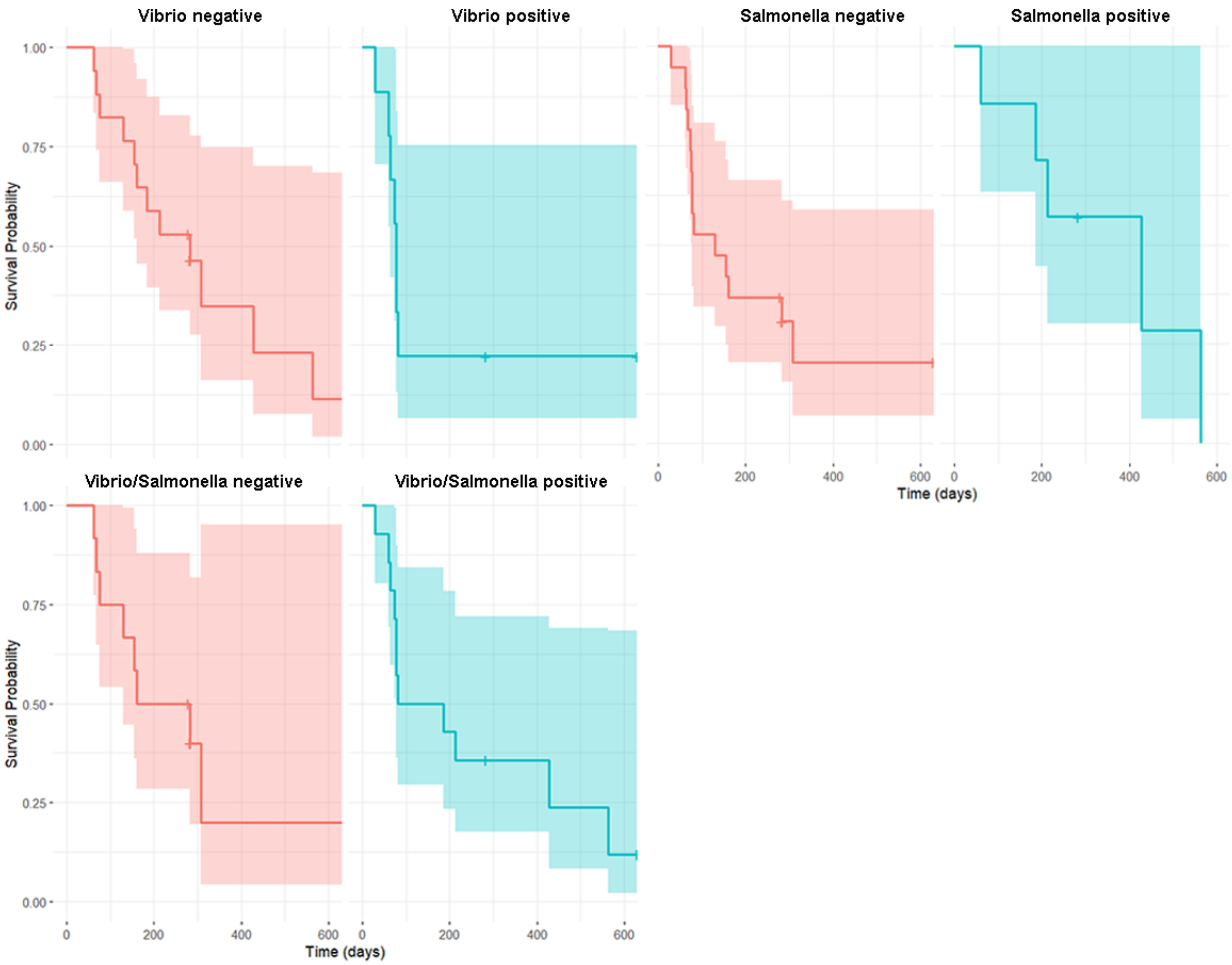

FIGURE 3.2. Post-fledging survival of White Ibis from two urban colonies (one in the coast, one inland) in south Florida tracked via GPS from capture until February 2025 or until failure was registered. The coastal colony is located in an estuary in Martin County and the inland colony is located in a golf course community in Palm Beach County. Survival was calculated using Cox proportional-hazards models run as three separate models: for *Vibrio* and *Salmonella* shedding status separately and also combined (i.e., "*Vibrio*/*Salmonella*") to capture the impact of infection with either pathogen. Neither *Vibrio* nor *Salmonella* significantly impacted post-fledging survival. Shaded areas represent standard error.

# CHAPTER 4

# WHAT DRIVES PEOPLE TO FEED URBAN WILDLIFE: WHITE IBISES IN SOUTH FLORIDA AS A CASE STUDY[1]

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[1] Seixas, J. S., Pienaar, E. F., Hernandez, S. M. To be submitted to a peer-reviewed journal.

## ABSTRACT

Wild bird feeding is a global practice gaining increasing attention in urban ecology. Most discussions address the feeding of backyard songbirds, while feeding of larger birds such as waterbirds is understudied, even though the latter are associated with negative impacts to both humans and birds. We explored the motivations behind supplementary feeding of White Ibises (*Eudocimus albus*) in south Florida and examined the implications of this practice for human-wildlife coexistence. We deployed an online survey to 507 Florida residents to assess demographic and socio-psychological factors associated with feeding ibises. Responses revealed that 35% of participants feed ibises at least occasionally, with some feeding them daily. Individuals who fed ibises tended to be younger, more likely to own pets and use bird feeders, and exhibited a strong emotional connection with ibises, yet often display lower awareness of the social and ecological consequences of bird feeding. Conversely, individuals who did not feed ibises expressed neutral attitudes towards ibises, primarily underpinned by a belief that birds can acquire sufficient natural food and lack of interest in feeding. Our results further indicated that feeding is primarily driven by egocentric values such as entertainment and stress relief. Increased feeding frequencies were correlated with motivations such as personal pleasure, nurturing, and companionship, indicating important psychological benefits to humans, which may conversely contribute to issues such as reduced natural foraging and heightened pathogen exposure in ibises. Our findings suggest that supplementary feeding is an important activity for Florida residents and that targeted public education strategies can be helpful in reframing human-ibis interactions and promoting coexistence in shared urban spaces.

## INTRODUCTION

Every year, over 50 million Americans feed wild birds at home, spending over US$5 billion on bird food and feeders (U.S. Fish and Wildlife Service 2016). This widespread practice not only enhances human well-being, by providing a deeper connection with nature and providing a sense of purpose, but it also benefits birds by increasing their chances of survival and reproductive success and improving their overall body condition (Soulsbury and White 2015; Jones 2018; Evans and Gawlik 2020). However, supplemental feeding can also have adverse effects. Birds may experience stress from crowding, reduced activity levels, increased risk of pathogen transmission, and a nutritionally inadequate diet (Becker et al. 2015; Bradley and Altizer 2007; Murray et al. 2016; Catto et al. 2021; López-García et al. 2021). Despite these significant impacts on avian communities, bird feeding remains an understudied and poorly monitored phenomenon in the US, particularly on non-passerine species (Horn and Johansen 2013).

People's motivations for feeding birds vary depending on numerous factors including demographics, culture, and target species. Motivations can be broadly categorized as 1) for conservation purposes (to benefit wild bird populations); 2) for personal benefit (to entertain, educate, or relax); and 3) to provide care to individual animals (Ishigame and Baxter 2007; Galbraith et al. 2014; Jones 2018; Thabethe and Downs 2018; Clark et al. 2019; Schreiber 2019). Motivations for feeding wild birds are complex and likely include a combination of the motivations mentioned above. For instance, an individual that feeds birds for conservation purposes might be doing so because they feel like there are not enough individuals of a given species in their area and/or because they feel they have the moral duty towards *undoing the harm that humans have done to the environment*. People may also seek a form of companionship through feeding birds (Jones 2018; Clark et al. 2019; Schreiber 2019). With increasing concerns about a “loneliness epidemic” (Bound Alberti 2018), capturing people’s need for connecting with wildlife through wildlife feeding may add an important layer to explain motivations for feeding.

Opinions and motivations towards feeding birds also differ depending on taxonomy. While feeding songbirds is broadly accepted by the general public, ornithological associations (e.g., National Audubon Society; Groo 2018) and sometimes also by the scientific community (Robb et al. 2008; Beck et al. 2015), as Jones and Reynolds (2008) noted, feeding certain birds (e.g., pigeons and waterfowl) tend to be accompanied by opposing perspectives (Coluccy et al. 2001; Perry et al. 2020). For those species, feeding tends to be associated with the aggravation of human-wildlife conflicts, particularly in urban areas. For example, Canada Geese (*Branta canadensis*) are problematic species in multiple US states and feeding these birds is thought to contribute to an increase in their abundance and promotion of nuisance behaviors (Coluccy et al. 2001; Titchenell and Lynch 2010; Johannes 2022). Most studies addressing people’s attitudes and motivations towards feeding birds focus on passerines. However, understanding what drives people to feed species that are, or could potentially become, nuisances is essential to prevent or mitigate conflicts.

The White Ibis (*Eudocimus albus*; “ibis” hereafter) is a charismatic wading bird commonly found in urban areas in south Florida. Ibises are frequently found in urban parks, landfills, zoos, and backyards foraging on lawns and artificial ponds. Although naturally a predator of small fish and invertebrates, urban ibises consume large amounts of anthropogenic food, commonly in the form of simple carbohydrates provided by the public (Fig. 4.1; Murray et al. 2018). This diet shift was correlated with a higher foraging site fidelity, reduced movement, altered movement behavior seasonality, and lower body condition scores in highly urbanized ibises (Murray et al. 2018; Kidd-Weaver et al. 2020; Teitelbaum et al. 2020). Individuals showing a high foraging site fidelity to urban parks were also found to be shedding pathogens such as *Salmonella* spp. at higher rates, indicating important direct and indirect impacts of supplementary feeding on ibis health and ecology (Murray et al. 2021). Ibises are currently liked by the public and are not regularly involved in conflicts with humans that elicit management actions (Curry, unpublished data). However, this scenario could rapidly change if feeding becomes more widespread and contributes to urban ibis population growth. For instance, many human-wading bird conflicts involve their breeding colonies, which are associated with unpleasant odors, noise, and risk of disease transmission (Perry et al. 2020). Ibises already breed successfully in urban environments (Seixas 2021). Although currently small and few in number, these colonies could become more numerous if more birds were attracted to urban areas and potentially mark the onset of significant conflicts.

Urban environments can play an important role in the conservation of local species. For instance, urban breeding colonies can function as buffers keeping recruitment stable even in years of poor productivity in natural rookeries (Evans et al. 2022). Like many waterbird species, ibises play an important role in their natural ecosystem (Kushlan 1979; Frederick et al. 2009). Specifically, ibis nesting pairs are used as an indicator species for the Everglades restoration efforts (Frederick et al. 2009). With the possibility of the urban ibis population growing, maintaining the current acceptance of this species by the public is vital. Feeding is currently one of the most direct ways that the public engage with ibises. While providing some benefits to humans, it has the potential to change the behavior of these birds, potentially making them a nuisance in the future. We designed this study to describe the attitudes and motivations of the public in south Florida towards feeding ibises to understand how to maintain and promote human-ibis coexistence in urban areas.

## METHODS

### *Survey design*

This study aimed to investigate the motivations that influence ibis feeding practices among residents of South Florida. We hired Qualtrics Research Services to distribute the survey online to adult (18+ years-old) residents of Palm Beach and Martin Counties. The final survey took approximately 15 min to complete. In Palm Beach and Martin Counties, 17-34% of households reported speaking a language other than English at home and 16-27% of the population identified as Hispanic or Latino (US Census 2023). To account for these non-English speakers, translated versions of the survey were available in Spanish and Portuguese. To ensure quality of responses, we included attention-check questions, made responses mandatory for all items (except income), and discarded any surveys completed in less than four minutes, a threshold determined during a soft launch with 20 participants.

Respondents provided demographic information on their age, gender, gross annual household income and educational levels, if they were seasonal or year-round residents of Florida, whether they owned pets, which pet(s) they owned, how many people lived with them (including children), and whether they used a bird feeder at home, and if so, how often. We then asked participants about their perceptions and attitudes toward ibises. They rated their level of liking for the birds (assessed on a five-point scale, from 1 “strongly dislike” to 5 “strongly like”), described the range of emotions experienced when encountering them (for example, joy, calm, irritation), and shared their overall perceptions regarding the birds’ presence and potential changes in population. The survey also inquired about feeding behaviors, asking respondents whether they fed ibises, how frequently they engaged in this activity, the locations where feeding occurred (such as at home, in parks, parking lots, or at the beach), the types of food provided (i.e., bread or snacks, pet (dog or cat) food, fish or seafood (ibises' natural prey (Kushlan 1979)), nuts, fruits or vegetables, leftovers, or "*whatever I have in my pocket*"), and whether they invested financially in food specifically for feeding the birds. To further explore the socio-psychological drivers behind the behavior, the survey included a series of Likert-scale statements (from 1 "strongly disagree" to 5 "strongly agree") designed to measure various latent constructs. These constructs encompassed motivations (such as egocentric reasons, moral duty, conservation support, nurturing intentions, and companionship), as well as perceptions of risk associated with feeding (distinguished into risk sensitivity regarding concern for potential ibis nuisance behaviors and risk susceptibility, the responsibility of feeders for aggravating those behaviors). Additional items were included to assess respondents' awareness of the ecological impacts of feeding and the degree to which they anthropomorphized ibises.

### *Statistical analysis*

Survey items were intentionally designed to reflect the key socio-psychological constructs proposed and they were assembled accordingly for analysis. We first evaluated the internal consistency of our survey items using Cronbach's alpha (implemented via the R package psych). Cronbach's alpha is a reliability coefficient that estimates how closely related a set of items are as a group, essentially measuring whether they consistently reflect the same underlying construct. In our analysis, we adopted a minimum cut-off of 0.6, with items falling below this threshold, or those that reduced the overall reliability of a construct, being excluded from further analysis. This step ensured that each socio-psychological construct (e.g., egocentric motivations, risk perceptions) was measured by items that were sufficiently inter-correlated. Following the reliability assessment, we performed Exploratory Factor Analysis (EFA) using the R package lavaan to determine the latent factor structure underlying our multi-item measures. EFA is a statistical technique that identifies the smallest number of unobserved (latent) variables that can explain the patterns of correlations among observed variables. In our study, EFA was used to confirm that items designed to capture specific constructs loaded coherently on distinct factors, thereby validating their dimensionality. We applied varimax rotation, a type of orthogonal rotation, which maximizes the variance of loadings on each factor and produces uncorrelated, easily interpretable factors. In line with common practice and recommendations in the literature (Watkins 2018; Goretzko et al. 2021), we retained only factors with eigenvalues of 1 or greater (the Kaiser criterion; Kaiser 1960). Finally, composite scores for each construct were computed by multiplying individual item responses by their corresponding factor loadings, summing these weighted scores, and dividing by the number of items retained, thus providing a robust measure of each latent variable for subsequent analysis.

For demographic responses reported in ranges (e.g., age and income), we used the median of the range for analyses. Education was converted into approximate years of study for each option (e.g., 12 years for completed high school level). We employed Wilcoxon rank-sum tests to compare ranked (e.g., Likert scale) responses and chi-square tests for binary responses (R package RVAideMemoire) from feeders and non-feeders, and one-way ANOVAs to examine differences across varying frequencies of feeding, which were rated on a scale from one ("*only occasionally*") to five ("*every day*"). We performed a linear discriminant analysis (R package MASS) to evaluate which variables best discriminated between different feeding frequencies.

The proportion of variance explained by each discriminant function was used to assess the contribution of each axis to group separation. Predictor variables in this analysis included feeding motivation constructs (most were included separately due to correlation, i.e., coefficient > |0.5|), financial investment in feeding, pet and bird feeder ownership, attitudes toward ibises, preferred feeding locations, types of food provided, perceived risk (both sensitivity and susceptibility), awareness of feeding impacts, degree of anthropomorphism, emotional responses (categorized as positive (e.g., joy, calm, love, excitement), no emotion, or negative (e.g., irritation, sadness, anger, disgust, fear)), loneliness (measured on a ten-point scale), and demographic factors (such as age, education, gender, income, duration of residence in Florida, county, and residential status). Generalized Linear Models (GLMs) that accounted for binomial data were applied to identify the key socio-psychological factors influencing the decision to feed or not feed ibises using the same variables above, excluding those related to feeding behavior (i.e., motivations, locations, and food items provided). Candidate models were compared using the Akaike Information Criterion (AIC) scores, with the best-fit model having the lowest AIC. We determined variables with $p \leq 0.05$ to be statistically significant. All analyses were conducted in R (v4.3.3).

## RESULTS

### *Demographics*

Responses were collected between November and December 2024. We received total of 696 responses, out of which we retained 507 valid responses (73%) for analysis after quality control measures were applied. Most respondents identified themselves as female (63%) with a median age of 59.5 years. Participants reported a median education level of 14 years and a median household income of $62,000 USD. They had lived in Florida for a median of 20 years, with most (96%) identifying as year-round residents compared to seasonal residents (3.75%). The majority resided in Palm Beach County (89%), while 11% lived in Martin County. The median household size was 2 individuals, and 24% of respondents reported having children at home. More than half of the respondents (55%) owned pets, although only 4.93% owned a pet bird. Bird feeder ownership was reported by 24% of participants and they used the feeder regularly (a median score of 5 on a 1 “only occasionally” to 5 “every day” scale). The median loneliness score was 3 on a 10-point scale on the frequency at which they feel lonely (from 1 “never” to 10 “always”).

A total of 176 (35%) respondents indicated that they feed ibises (Fig. 4.2). Compared to non-feeders (n = 331), feeders were generally younger, had fewer years of education, made lower income, lived in Florida for more years, mostly resided in Palm Beach County, and shared their household with more people, including children, despite feeling lonelier overall (Tables 4.1 and S1). They were also more likely to own a pet, including birds, used bird feeders more often, liked ibises more, and reported feeling mostly positive emotions when seeing ibises (Table S2). We detected no significant differences in gender and resident status (i.e., year-round or seasonal) between feeders and non-feeders. Regarding participant feeding frequency (scored from 1 “only occasionally” to 5 “every day”), frequent feeders used bird feeders more often than those feeding ibises infrequently. No other significant demographic differences were detected between feeders.

### *Opinions towards ibises*

Regarding opinions towards ibises, respondents generally expressed liking for the birds, with a median liking score of 1 on a scale ranging from -2 (“strongly dislike”) to 2 (“strongly like”). The majority (85%) reported feeling positive emotions such as joy, calm, or love when encountering ibises, whereas only 1.78% reported negative emotions, and 13% expressed feeling no emotions. Respondents were neutral about whether they thought the ibis population should increase (median = 0 on a scale from -2 “decrease by a large amount” to 2 “increase by a large amount”), and the median frequency of ibis feeding was 2 (scale from 1 “only occasionally” to 5 “every day”).

### *Anthropomorphism*

Feeders agreed with prompts that anthropomorphized ibises more than non-feeders ($W$ = 15945, $p < 0.001$; Tables 4.2 and S3) and participants who feed ibises more frequently tend to anthropomorphize ibises more ($F(171) = 7.54$, $p < 0.001$).

### *Awareness*

Feeders had significantly lower awareness of the negative impacts of feeding ($W$ = 38685, $p < 0.001$) compared to non-feeders, however responses to statements regarding awareness were not significantly different between participants feeding ibises at different frequencies ($F(171) = 1.05$, $p = 0.4$; Tables 4.2 and S3).

### *Risk sensitivity and susceptibility*

Feeders exhibited higher risk sensitivity ($W = 25336$, $p = 0.015$, Table S4) but lower risk susceptibility ($W = 33169$, $p = 0.010$, Table S5) than non-feeders. These results suggest that feeders, while more aware of the potential human-wildlife conflicts caused by ibises, tend to perceive themselves as less directly responsible for any negative consequences. Risk sensitivity

($F(171) = 2.24$, $p = 0.07$) and risk susceptibility ($F(171) = 1.74$, $p = 0.14$) were not significantly different between respondents feeding ibises at different frequencies.

### *Feeding behavior models*

The GLM comparing feeders and non-feeders indicated that having a bird feeder ($\beta = 1.68$, SE = 0.29, $p < 0.001$), exhibiting higher levels of anthropomorphism ($\beta = 1.84$, SE = 0.34, $p < 0.001$), residing in Florida for more years ($\beta = 0.05$, SE = 0.02, $p = 0.02$), and being more concerned about human-ibis conflicts ($\beta = 0.52$, SE = 0.17, $p = 0.003$) were positively associated with feeding behavior, whereas higher awareness of the negative impacts of feeding ($\beta = -2.18$, SE = 0.44, $p < 0.001$) and older age ($\beta = -0.030$, SE = 0.009, $p < 0.001$) were negatively associated. The best fit model included predictor variables that were significant based on the Wilcoxon rank-sum and chi-square tests (Table 4.3).

### *Food types provided and feeding locations*

When comparing the types of food fed to ibises, participants indicated that they provide bread and snacks (such as chips) most often and that they almost never feed ibises fish or seafood, or items similar to their natural diet (Fig. 4.3 and Table S6). Respondents feeding ibises more frequently fed more “bird seeds” to ibises ($F(171) = 3.12$, $p = 0.016$). No significant differences between feeders were observed for the other food sources available for selection (i.e., bread or snacks, pet (dog or cat) food, fish or seafood, nuts, fruits or vegetables, leftovers, or “*whatever I have in my pocket*”; $p > 0.05$). Urban parks and at home were the two most common locations where participants feed ibises. There were no significant differences in locations chosen depending on feeding frequency, with the exception of feeding at the beach, which was significantly more common among frequent feeders ($F(171) = 2.45$, $p = 0.048$). Additionally, feeders were more likely to spend money on the activity with increasing frequency in feeding ($F(171) = 11.4$, $p < 0.001$), with over 43% (n = 75) of participants feeding ibises between monthly and daily investing financially on the activity, compared to 9% (n = 101) of people who only feed occasionally or seasonally.

### *Motivations for feeding*

Some motivational constructs were significantly different between participants feeding ibises at different frequencies: egocentric motivations ($F(171) = 5.92$, $p < 0.001$), nurturing intentions ($F(171) = 5.51$, $p < 0.001$), and feeding to get a sense of companionship ($F(171) = 7.70$, $p < 0.001$) all increased with feeding frequency (Table S7). We did not detect a significant difference for constructs including having a moral duty to feed ($F(171) = 1.24$, $p = 0.3$) and feeding as a means to promote ibis conservation ($F(171) = 2.34$, $p = 0.06$) with feeding frequency.

### *Feeding frequency analysis*

To further explore the drivers of feeding frequency, a series of linear discriminant analyses were constructed (Table 4.4). The analyses identified four discriminant functions. The first two functions accounted for most of the variance between groups and together explained over 70% of the total variance of each analysis performed, indicating that these two dimensions captured most of the separation among feeding behaviors. Variables such as spending money to feed ibises and anthropomorphizing birds most strongly explained the variation between participants feeding ibises at different frequencies.

### *Reasons for not feeding*

We asked non-feeders some questions regarding the reasons for them to not engage in feeding ibises (Table S8). They reported a mean response of 3.76 ± 1.01 (Likert scale from 1 (strongly disagree) – 5 (strongly agree), ± SD) for the statement "*I am not interested in feeding white ibises*" and 3.78 ± 0.85 for "*there is sufficient food available in the environment. White ibises don't need my help*". The statement "*there are enough people who feed white ibises, so I don't need to*" received the lowest mean response from non-feeders of 3.08 ± 0.73, followed by "*I do not feed white ibises because I was told not to feed them*" with 3.48 ± 1.11.

## DISCUSSION

A large proportion of south Floridians engage in feeding ibises, with over one third of our surveyed population participating in this activity at least occasionally, indicating that this practice is widespread and likely an important activity to Florida residents. Our analyses revealed that demographic differences between feeders and non-feeders were primarily evident in age and the duration of residency in Florida. Specifically, younger individuals and those who have lived longer in Florida were more likely to feed ibises. Feeders also tended to be from Palm Beach County, have fewer years of education, and lower incomes. These findings both align with and diverge from previous studies; for example, Davies et al. (2012) and Galbraith et al. (2014) found that highly educated and high-income households were less likely to engage in wildlife feeding, reflecting our observations, but contrasting with results from Fuller et al. (2012). The relationship between age and feeding is less clear and demographic factors have been overall proposed as poor predictors of feeding (Galbraith et al. 2014; Henson et al. 2023). Our data suggest that a younger demographic, likely comprised of parents, is more actively involved in feeding activities. Indeed, a higher proportion of feeders reported having children in their households compared to non-feeders, which implies that feeding may also serve a role in child entertainment or education. However, when we specifically examined whether participants fed ibises for child-related purposes, the responses did not significantly influence any of the socio-psychological constructs studied, a finding that would be better addressed by future studies focusing on the role of feeding in parenting. Overall, our results align with the broader literature on wild bird feeding behaviors highlighting the complex interplay of socioeconomic, familial, and cultural factors in shaping feeding practices, which are highly variable between geographic locations and taxonomy of target species (Thabethe and Downs 2018; Rollinson et al. 2003; Ishigame and Baxter 2007; Martin and Greig 2019; Horn and Johansen 2013; Clark et al. 2019).

Most ibis feeders in our study reported owning pets, particularly pet birds. Pet owners tend to have more favorable attitudes toward a wide range of wild animal species and engage more regularly in animal-related activities, including wildlife feeding (Bjerke and Kleiven 2003). It appears that the care and nurturing provided to domesticated pets can extend to a broader interest in supporting local wildlife. The experience of caring for a pet may foster empathy and reduce fear toward wild animals, thereby encouraging pet owners to participate in feeding behaviors (Paul and Serpell 1993; Bowd 1984). In our sample, this association suggests that individuals who are already predisposed to maintain a close relationship with animals in a domestic setting are more likely to engage in supplementary feeding of ibises. Additionally, respondents who feed ibises frequently use bird feeders more often as well, indicating a commitment to support wild birds in general, but also reflecting a similar drive to feed birds across taxonomical groups. Only 41 participants reported to use a bird feeder but not feed ibises, while 96 reported to feed ibises but not use a bird feeder. Motivations to feed ibises as opposed to passerines were not investigated, but they could be influenced by the more direct experience from feeding ibises as these birds can be readily handfed (Wilson et al. 2024).

Ibis feeding tends to occur in urban parks and at home, a pattern that mirrors both the habitat preferences of ibises and the urban landscapes in south Florida (Kidd-Weaver et al. 2020; Teitelbaum et al. 2020). As a state dominated by wetlands and dependent on extensive water management as a result of development, anthropogenic environments are largely characterized by abundant ponds and canals that offer easy access to water to waterbirds (Bueno et al. 1995). Urban areas in Florida are largely suburban, where houses have ample backyards and urban parks are common. For these reasons, many houses in Florida are constructed adjacent to or incorporate water features, which makes feeding sites readily accessible to both the birds and the people who feed them. Ibises regularly return to areas where they are routinely fed (Teitelbaum et al. 2020; Murray et al. 2021). Regarding the types of food offered, our findings indicate that bread and snack foods such as chips are the most common items provided, followed by bird seeds. In contrast, natural food sources that are most similar to their natural prey like fish and seafood are rarely offered. This pattern suggests that many feeders choose foods based on preconceived beliefs about what is appropriate for birds rather than on an understanding of ibis ecology. Because individuals feeding ibises more often tend to spend money to do so, their choices in food can be considered intentional, while people who just feed ibises occasionally may be choosing food based on convenience. The common provision of bread and bird seeds may reflect a generalization of avian diets, even though ibises are primarily adapted to consume aquatic prey (Kushlan 1979). Similar trends have been reported in other studies, where food choices often do not align with the natural dietary needs of the birds, with bread being a common food type provided (Galbraith et al. 2014; Thabethe and Downs 2018; Henson et al. 2023).

Our findings suggest that the motivations behind feeding ibises are multifaceted and largely driven by personal and emotional benefits. Individuals feeding ibises more frequently scored significantly higher on egocentric motivations as well as on nurturing and companionship constructs, indicating that primary drivers to feed ibises frequently stem from purposes such as personal pleasure, stress relief, loneliness alleviation, and as a concern for the birds' wellbeing. Feeding for self-pleasure, desire to nurture the birds, and connecting with nature were repeatedly reported in the literature as the primary motivators for this activity, with their relative importance varying by geographic location and avian taxonomy (Ishigame and Baxter 2007; Cox and Gaston 2016; Reynolds et al. 2017; Thabethe and Downs 2018; Clark et al. 2019; Schreiber 2019). While responses from feeders also suggested an influence from moral duty and conservation rationales for feeding ibises, these motivations were not as strongly associated with feeding frequency as the more self-oriented drivers. This pattern may reflect a tendency among feeders in south Florida to prioritize immediate personal and emotional gains over broader conservation goals. The significant role of companionship in our analysis suggests that, for a subset of individuals, feeding ibises may serve as a means to alleviate loneliness and foster a sense of companionship with wildlife, a pattern likely to aggravate given the increasing widespread social isolation resulting from the increased use of technology and remote working (Daniel et al. 2017; O'Day and Heimberg 2021). Such findings align with the growing body of literature that underscores wildlife feeding as an accessible form of interaction, offering both direct psychological rewards and indirect benefits by potentially enhancing one's connection with the environment (Jones 2010; Reynolds et al. 2017).

Participants’ perceptions of ibises and the associated human-wildlife conflicts indicate a complex interplay between emotional connection and a limited recognition of broader ecological consequences. Our results showed that feeders agreed more strongly with prompts that anthropomorphize ibises compared to non-feeders, suggesting that these individuals tend to ascribe human-like qualities and emotional depth to the birds. This tendency to view ibises as personable and relatable demonstrates an intimate interaction between feeder and bird that blurs the boundaries between human and wildlife (Jones 2018). Anthropomorphism was stronger among feeders feeding ibises frequently and it is likely a key habit reinforcer contributing to both the long-term maintenance of this behavior and its intensification (Horvath and Roelans 1991). While feeders exhibited higher risk sensitivity, indicating that they acknowledge common sources of human-ibis conflicts such as pathogen transmission and accumulation of droppings in public paths, they concurrently reported that they do not believe feeding to be an aggravator. This reflects increased risk awareness possibly resulting from the more frequent interactions with ibises compared to non-feeders, but a dissonance on their role in these dynamics. Similarly, Dubois and Fraser (2013) and Usui et al. (2024) reported that local stakeholders recognized wildlife feeding risks yet often deflected personal accountability. Feeders were also less cognizant of the negative impacts of feeding on ibises, such as changes in behavior and health impacts, further reinforcing their lack of awareness of the negative consequences associated with feeding to both humans and wildlife despite indicating a stronger affinity for the birds. In fact, feeding ibises has significantly disrupted their movement behaviors and is indirectly associated with a higher exposure to pathogens resulting from their increased foraging site fidelity to common feeding locations (Kidd-Weaver et al. 2020; Murray et al. 2021; Teitelbaum et al. 2022). For feeders, personal enjoyment and emotional gratification are often prioritized over critical assessments of long-term ecological outcomes (Cox and Gaston 2016; Reynolds et al. 2017).

Although we detected key differences in the responses between feeders and non-feeders throughout the survey, feeding behavior was strongly predicted by a lower age, longer duration of residency in Florida, higher risk sensitivity and degree to which they anthropomorphize ibises, and lower awareness of the potential impacts of feeding on ibises. These results suggest that feeding behavior stems from the interplay of multiple social and psychological variables, but that differences between feeders and non-feeders may extend beyond these predictors. Non-feeders, as our data suggest, tend not to engage in supplementary feeding largely because they are more conscious of the impacts of feeding on ibises, they perceive that ibises already have sufficient access to natural food sources, and they are not interested in the activity. Although their responses were generally neutral to statements asking about why they do not engage in feeding, it is possible that their abstention does not reflect an active opposition to bird feeding, which suggests the absence of deterrents for non-feeders to eventually adopt this behavior. Literature on the attitudes of non-feeders is conflicting, with studies reporting that non-feeders are not opposed to feeding, while others finding that they condemn the activity (Rollinson et al. 2003; Galbraith et al. 2014). These insights underscore the potential of public education as a preventative strategy. By disseminating clear, evidence-based information on the health and ecological risks associated with supplementary feeding, education campaigns can help reshape public perceptions. Well-designed targeted messaging emphasizing the health and welfare of wildlife can be particularly persuasive, particularly for ibises, given that the public likes and cares for them (Ballantyne and Hughes 2006; Marion et al. 2008; Dubois and Fraser 2013). However, in this study, respondents indicated a neutral response to anti-feeding messaging, which may highlight the need for more targeted efforts. Aligning these efforts with broader conservation messages can reinforce the idea that maintaining natural foraging behaviors is beneficial not only for ibises but also for urban wildlife communities as a whole (Galbraith et al. 2014; Jones 2018).

## CONCLUSIONS

Feeding ibises and potentially other wading bird species seems to be an important activity for Floridians, enhancing well-being and providing a sense of purpose through helping these birds survive. However, while this practice might be beneficial to humans, it poses significant disruptions to ibises' natural behaviors and ecology, by promoting sedentarism in a naturally nomadic species accustomed with frequent long-distance movements, while also promoting human-ibis conflicts (Frederick et al. 1996). Wading birds are arguably good target species to promote in the growing coexistence agenda as they are aesthetic and are usually associated with few conflicts that are generally easy to manage and prevent (Grant and Watson 1995; Hoy 2017; Moreira et al. 2018; Perry et al. 2020). As such, the main driver of human-wading bird conflicts is supplementary feeding by aggregating birds and creating dependence in urban spaces. As indicated by our results, the general population in Florida likes ibises and are satisfied with their current abundance, facilitating conservation campaigns as they need only to maintain status quo, but highlighting the need to not intensify and maybe reduce feeding activities to prevent the establishment of future conflicts. Public education and community engagement are critical to mitigate feeding of ibises, as they can help disseminate evidence-based information on the ecological drawbacks of supplementary feeding and promote behaviors that support balanced, long-term coexistence. Alternative bird-friendly activities involving children that also entice scientific curiosity, such as birding, can be particularly effective for residents of south Florida.

Ultimately, fostering coexistence in urban landscapes is a transformative opportunity: by discouraging feeding practices that undermine ecological integrity and by encouraging natural interactions with wildlife, cities can become diverse, resilient systems that nurture both human and avian well-being.

## REFERENCES

Ballantyne, R., & Hughes, K. (2006). Using front-end and formative evaluation to design and test persuasive bird feeding warning signs. *Tourism Management*, *27*(2), 235–246.

Beck, A. M., Melson, G. F., Da Costa, P. L., & Liu, T. (2001). The educational benefits of a ten-week home-based wild bird feeding program for children. *Anthrozoos*, *14*(1), 19–28.

Becker, D. J., Hall, R. J., Forbes, K. M., Plowright, R. K., & Altizer, S. (2018). Anthropogenic resource subsidies and host –parasite dynamics in wildlife. In *Philosophical Transactions of the Royal Society B: Biological Sciences*.

Bound Alberti, F. (2018). This “modern epidemic”: Loneliness as an emotion cluster and a neglected subject in the history of emotions. *Emotion Review*, *10*(3), 242–254.

Bowd, A. D., & Santrock, J. W. (1984). Fears and understanding of animals in middle childhood. *Journal of Genetic Psychology, 145*(1), 143–144.

Bradley, C. A., & Altizer, S. (2007). Urbanization and the ecology of wildlife diseases. *Trends in Ecology and Evolution*, *22*(2), 95–102.

Bueno, J. A., Tsihrintzis, V. A., & Alvarez, L. (1995). South Florida greenways: a conceptual framework for the ecological reconnectivity of the region. *Landscape and Urban Planning*, *33*(1–3), 247–266.

Catto, S., Sumasgutner, P., Amar, A., Thomson, R. L., & Cunningham, S. J. (2021). Pulses of anthropogenic food availability appear to benefit parents, but compromise nestling growth in urban red-winged starlings. *Oecologia*, *197*(3), 565–576.

Clark, D. N., Jones, D. N., & James Reynolds, S. (2019). Exploring the motivations for garden bird feeding in south-east England. *Ecology and Society, 24*(1).

Coluccy, J. M., Drobney, R. D., Graber, D. A., Sheriff, S. L., & Witter, D. J. (2001). Attitudes of central Missouri residents toward local giant Canada geese and management alternatives. *Wildlife Society Bulletin*, *29*, 116–123.

Cox, D. T. C., & Gaston, K. J. (2016). Urban bird feeding: Connecting people with nature. *PLoS ONE*, *11*.

Davies, Z. G., Fuller, R. A., Dallimer, M., Loram, A., & Gaston, K. J. (2012). Household factors influencing participation in bird feeding activity: A national scale analysis. *PLoS ONE*, *7*.

Dubois, S., & Fraser, D. (2013). Local attitudes towards bear management after illegal feeding and problem bear activity. *Animals*, *3*(3), 935–950.

Evans, B. A., & Gawlik, D. E. (2020). Urban food subsidies reduce natural food limitations and reproductive costs for a wetland bird. *Scientific Reports*, *10*(1), 14021.

Frederick, P., Gawlik, D. E., Ogden, J. C., Cook, M. I., & Lusk, M. (2009). The White Ibis and Wood Stork as indicators for restoration of the everglades ecosystem. *Ecological Indicators*, *9*(6).

Frederick, P. C., Bildstein, K. L., Fleury, B., & Ogden, J. (1996). Conservation of large, nomadic populations of White Ibises (*Eudocimus albus*) in the United States. *Conservation Biology*, *10*(1), 203–216.

Fuller, R. A., Irvine, K. N., Davies, Z. G., Armsworth, P. R., & Gaston, K. J. (2012). Interactions between People and Birds in Urban Landscapes. In *Urban Bird Ecology and Conservation* (pp. 249–266). University of California Press.

Galbraith, J. A., Beggs, J. R., Jones, D. N., McNaughton, E. J., Krull, C. R., & Stanley, M. C. (2014). Risks and drivers of wild bird feeding in urban areas of New Zealand. *Biological Conservation*, *180*, 64–74.

Goretzko, D., Pham, T. T. H., & Bühner, M. (2021). Exploratory factor analysis: Current use, methodological developments and recommendations for good practice. *Current Psychology*, *40*(7), 3510–3521.

Grant, K. R., & Watson, J. (1995). Controlling nuisance egret and heron rookeries in Oklahoma. *Great Plains Wildlife Damage Control Workshop Proceedings*, *April*, 32–33.

Groo, M. (2018). When it’s okay (or not) to feed birds. National Audubon Society. https://www.audubon.org/news/when-its-okay-or-not-feed-birds

Henson, E., McLeod, E. M., Weston, M. A., & Miller, K. K. (2023). Bird feeding at urban wetlands: A comparison of demographics, attitudes and norms between feeders and non-feeders. *Science of the Total Environment*, *891*.

Horn, D. J., & Johansen, S. M. (2013). A comparison of bird-feeding practices in the United States and Canada. *Wildlife Society Bulletin*, *37*(2), 293–300. https://doi.org/10.1002/WSB.281

Horvath, T., & Roelans, A. M. (1991). Backyard Feeders: Not Entirely for the Birds. *Anthrozoös*, *4*(4), 232–236.

Hoy, M. D. (2017). Herons and Egrets. In *Wildlife Damage Management Technical Series. 12.*

Ishigame, G., & Baxter, G. S. (2007). Practice and attitudes of suburban and rural dwellers to feeding wild birds in Southeast Queensland, Australia. *Ornithological Science*, *6*(1), 11–19.

Johannes, B. (2022). Urban wildlife management planning process and conflict mitigation: A case study of Denver's Canada Goose management plan. University of Nebraska-Lincoln, Lincoln, NE.

Jones, D. (2018). The Birds at My Table. In *The Birds at My Table*. Cornell University Press.

Jones, A. D. (2010). Seeking nature in the city: the implications of feeding wildlife. *Cox*, 72–75.

Jones, D. N., & James Reynolds, S. (2008). Feeding birds in our towns and cities: A global research opportunity. *Journal of Avian Biology*, *39*(3), 265–271.

Kaiser, H. F. (1960). The application of electronic computers to factor analysis. *Educational and Psychological Measurement*, *20*(1), 141–151.

Kidd-Weaver, A., Hepinstall-Cymerman, J., Welch, C. N., Murray, M. H., Adams, H. C., Ellison, T. J., Yabsley, M. J., & Hernandez, S. M. (2020). The movements of a recently urbanized wading bird reveal changes in season timing and length related to resource use. *PLoS ONE*, *15*(3), e0230158.

Kushlan, J. A. (1979). Feeding ecology and prey selection in the White Ibis. *The Condor*, *81*(4), 376.

López-García, A., Sanz-Aguilar, A., & Aguirre, J. I. (2021). The trade-offs of foraging at landfills: Landfill use enhances hatching success but decrease the juvenile survival of their offspring on white storks (*Ciconia ciconia*). *Science of the Total Environment*, *778*.

Martin, V. Y., & Greig, E. I. (2019). Young adults' motivations to feed wild birds and influences on their potential participation in citizen science: An exploratory study. *Biological Conservation*, *235*, 295–307.

Moreira, F., Martins, R. C., Catry, I., & D'Amico, M. (2018). Drivers of power line use by white storks: A case study of birds nesting on anthropogenic structures. *Journal of Applied Ecology*, *55*(5), 2263–2273.

Murray, M. H., Becker, D. J., Hall, R. J., & Hernandez, S. M. (2016). Wildlife health and supplemental feeding: A review and management recommendations. *Biological Conservation*, *204*, 163–174.

Murray, M. H., Kidd, A. D., Curry, S. E., Hepinstall-Cymerman, J., Yabsley, M. J., Adams, H. C., Ellison, T., Welch, C. N., & Hernandez, S. M. (2018). From wetland specialist to hand-fed generalist: Shifts in diet and condition with provisioning for a recently urbanized wading bird. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *373*(1745).

Murray, M. H., Hernandez, S. M., Rozier, R. S., Kidd, A. D., Hepinstall-Cymerman, J., Curry, S. E., Yabsley, M. J., Adams, H., Ellison, T., Welch, C. N., & Lipp, E. K. (2021). Site fidelity is associated with food provisioning and *Salmonella* in an urban wading bird. *EcoHealth*, *18*(3), 345–358.

Paul, E. S., & Serpell, J. A. (1993). Childhood pet keeping and humane attitudes in young adulthood. *Animal Welfare*, *2*(4), 321–337.

Perry, G., Boal, C., Verble, R., & Wallace, M. (2020). "Good" and "bad" urban wildlife. In *Problematic Wildlife II* (pp. 141–170). Springer, Cham.

Robb, G. N., McDonald, R. A., Chamberlain, D. E., & Bearhop, S. (2008). Food for thought: Supplementary feeding as a driver of ecological change in avian populations. *Frontiers in Ecology and the Environment*, *6*(9), 476–484.

Rollinson, D. J., O'Leary, R., & Jones, D. N. (2002). The practice of wildlife feeding in suburban Brisbane. *Corella*, *27*(2), 52–58.

Schreiber, H. (2019). Anthropogenic feeding of red kites in Switzerland: Motivations and consequences. M.S. Thesis, Zürcher Hochschule für Angewandte Wissenschaften, Winterthur, Switzerland.

Seixas, J. S. (2021). Urbanization of the White Ibis (*Eudocimus albus*): Reproductive productivity and nestling West Nile virus dynamics. University of Georgia, Athens, GA.

Soulsbury, C. D., & White, P. C. L. (2015). Human–wildlife interactions in urban areas: a review of conflicts, benefits and opportunities. *Wildlife Research*, *42*(7), 541–553.

Teitelbaum, C. S., Hepinstall-Cymerman, J., Kidd-Weaver, A., Hernandez, S. M., Altizer, S., & Hall, R. J. (2020). Urban specialization reduces habitat connectivity by a highly mobile wading bird. *Movement Ecology*, *8*(1).

Thabethe, V., & Downs, C. T. (2018). Citizen science reveals widespread supplementary feeding of African woolly-necked storks in suburban areas of KwaZulu-Natal, South Africa. *Urban Ecosystems*, *21*(5), 965–973.

Titchenell, M. A., & Lynch Jr, W. E. (2010). Coping with Canada Geese: Conflict Management and Damage Prevention Strategies. In *The Ohio State University*.

US Census Bureau. (2023). ACS 1-Year Estimates Data Profiles. https://data.census.gov/table?q=DP02&g=040XX00US12_050XX00US12099. Accessed March 2025.

US Fish & Wildlife Service. (2016) National survey of fishing hunting and wildlife-associated recreation. https://www.fws.gov/sites/default/files/documents/2024-06/fhw2016.pdf. Accessed June 2024.

Watkins, M. W. (2018). Exploratory Factor Analysis: A guide to best practice. *Journal of Black Psychology*, *44*(3), 219–246.

Wilson, C. A., Hernandez, S., Weil, J. N., Ezenwa, V. O., Altizer, S., & Hall, R. J. (2024). Human-provided food increases aggregation but does not change activity budgets in an urban wading bird. *Journal of Urban Ecology*, *10*(1).

TABLES

TABLE 4.1. Demographic and household profiles of respondents who feed ("feeder", n=176) and do not feed ("non-feeder", n=331) White Ibises. For feeders, the sample is further divided into infrequent (occasional or seasonal feeding) and frequent (at least once a month) feeders. We performed Wilcoxon rank-sum test for ranked responses and Chi-square tests for binary responses to compare feeders and non-feeders, and one-way ANOVAs to compare participants feeding at different frequencies.

| Category | Feeder (n = 176) | Non-feeder (n = 331) | Statistics | Infrequent feeder (n = 101) | Frequent feeder (n = 75) | ANOVA |
|---|---|---|---|---|---|---|
| Age (years, mean ± SD) | 46.7 ± 17.1 | 57.7 ± 16.0 | $W = 39587$, $p < 0.001$ | 47.8 ± 18.0 | 45.2 ± 15.7 | $F(171) = 1.04$, $p = 0.39$ |
| Gender (%) | 58.0(female) | 65.6 (female) | $\chi^2$ (1, n = 507) = 2.85, $p = 0.091$ | 53.4 (female) | 64.0 (female) | $F(171) = 1.00$, $p = 0.41$ |
| Education (years, mean ± SD | 14.7 ± 2.56 | 15.5 ± 2.64 | $W = 34598$, $p < 0.001$ | 14.7 ± 2.34 | 14.7 ± 2.83 | $F(171) = 1.46$, $p = 0.22$ |

| | | | | | | |
|---|---|---|---|---|---|---|
| Household income (mean ± SD, USD) | 61,184 ± 28,261 | 68,146 ± 28,284 | $W = 31258$, $p = 0.0093$ | 61,097 ± 27,600 | 61,301 ± 29,126 | $F(166) = 0.98$, $p = 0.42$ |
| Years lived in Florida (mean ± SD) | 16.9 ± 5.42 | 15.2 ± 6.51 | $W = 24854$, $p = 0.0020$ | 17.1 ± 5.08 | 16.7 ± 5.84 | $F(171) = 1.67$, $p = 0.16$ |
| Residence status (%, year-round or seasonal) | 98.3 (year-round) | 95.2 (year-round) | $\chi^2(1, n = 507) = 3.12$, $p = 0.077$ | 99.0 (year-round) | 97.3 (year-round) | $F(171) = 0.37$, $p = 0.83$ |
| County (%) | 93.2 (Palm Beach) | 86.7 (Palm Beach) | $\chi^2(1, n = 507) = 4.90$, $p = 0.027$ | 94.1 (Palm Beach) | 92.0 (Palm Beach) | $F(171) = 0.39$, $p = 0.82$ |
| People in household (mean ± SD, including oneself) | 2.77 ± 1.40 | 2.29 ± 1.25 | $W = 23666$, $p < 0.001$ | 2.69 ± 1.37 | 2.88 ± 1.44 | $F(171) = 1.04$, $p = 0.39$ |
| Has children in household (%) | 34.7 | 17.8 | $\chi^2(1, n = 507) = 18.0$, $p < 0.001$ | 30.7 | 40.0 | $F(171) = 1.94$, $p = 0.11$ |

| | | | | | | |
|---|---|---|---|---|---|---|
| Pet ownership (%) | 64.8 | 50.2 | $\chi^2$ (1, n = 507) = 9.93, $p = 0.002$ | 60.4 | 70.7 | $F(171) = 2.82$, $p = 0.095$ |
| Dog or cat ownership (%) | 64.2 | 48.3 | $\chi^2$ (1, n = 507) = 11.6, $p < 0.001$ | 59.4 | 70.7 | $F(171) = 2.12$, $p = 0.080$ |
| Bird ownership (%) | 10.2 | 2.1 | $\chi^2$ (1, n = 507) = 16.1, $p < 0.001$ | 8.9 | 12.0 | $F(171) = 2.82$, $p = 0.027$ |
| Other pet ownership (%, e.g., reptiles, fish, ferrets, etc.) | 14.8 | 7.9 | $\chi^2$ (1, n = 507) = 5.97, $p = 0.015$ | 14.9 | 14.7 | $F(171) = 1.35$, $p = 0.25$ |
| Bird feeder ownership (%) | 45.5 | 12.4 | $\chi^2$ (1, n = 507) = 69.1, $p < 0.001$ | 37.6 | 56.0 | $F(171) = 2.96$, $p = 0.021$ |

| | | | | | | |
|---|---|---|---|---|---|---|
| Frequency of bird feeder use (scored 0 [never] – 5 [every day], mean ± SD) | 2.07 ± 2.31 | 0.483 ± 1.91 | $W = 19094$, $p < 0.001$ | 1.67 ± 2.20 | 2.60 ± 2.34 | $F(171) = 3.57$, $p = 0.008$ |
| Likes ibises (scored -2 [strongly dislike] – 2 [strongly like], mean ± SD) | 1.23 ± 0.73 | 1.03 ± 0.79 | $W = 25099$, $p = 0.006$ | 1.17 ± 0.732 | 1.32 ± 0.71 | $F(171) = 0.60$, $p = 0.66$ |
| Wants ibis population to increase (scored -2 [decrease a large amount] – 2 [increase a large amount], mean ± SD) | 0.32 ± 0.79 | 0.21 ± 0.68 | $W = 27510$, $p = 0.20$ | 0.31 ± 0.61 | 0.35 ± 0.97 | $F(171) = 1.64$, $p = 0.17$ |
| Feels positive emotion towards ibises (%, joy, calm, love, excitement) | 92.6 | 80.7 | $\chi^2$ (1, n = 507) = 12.7, $p < 0.001$ | 91.1 | 94.7 | $F(171) = 0.43$, $p = 0.79$ |
| Feels negative emotion towards ibises (%, sadness, irritation, anger, disgust, fear) | 1.1 | 2.1 | $\chi^2$ (1, n = 507) = 0.63, $p = 0.43$ | 0.0 | 2.7 | $F(171) = 0.92$, $p = 0.45$ |

| | | | | | | |
|---|---|---|---|---|---|---|
| Feels no emotion towards ibises (%) | 16.9 | 6.8 | $\chi^2$ (1, n = 507) = 11.4, $p < 0.001$ | 7.9 | 4.0 | $F(171) = 0.39$, $p = 0.82$ |
| Frequency I feel lonely (0 [never] – 10 [always], mean ± SD) | 4.15 ± 2.98 | 3.10 ± 2.64 | $W = 23209$, $p < 0.001$ | 4.08 ± 2.88 | 4.24 ± 3.12 | $F(171) = 0.25$, $p = 0.91$ |

TABLE 4.2. Internal consistency and response patterns for various belief constructs related to White Ibis feeding behavior. Constructs assessed among feeders (and in some cases non-feeders) include egocentric motivations, moral duty, conservation support, nurturing intentions, companionship, anthropomorphism, awareness of feeding impacts, risk sensitivity, and risk susceptibility. Responses were recorded on a five-point Likert scale, with reliability coefficients (Cronbach's alpha) provided for each construct.

| Category | Description | Statements | Cronbach's alpha (mean ± SD) | Responses | |
|---|---|---|---|---|---|
| | | | | Feeder (mean ± SD, min, max) | Non-feeder (mean ± SD, min, max) |
| Egocentric | Feeding for self-gain | "Feeding white ibises gives me pleasure"<br>"Feeding white ibises is a stress reliever"<br>"Feeding white ibises makes me feel connected to nature"<br>"Feeding white ibises makes me feel less lonely"<br>"Feeding white ibises is part of my identity" | 0.83 ± 0.0082 | 2.40 ± 0.36, 1.24, 3.12 | NA |

| | | | | | |
|---|---|---|---|---|---|
| | | “I feed white ibises because it makes them happy”<br>“I get excited when I see white ibises coming back to me for food”<br>“I feed white ibises so that they stay in my area”<br>“I enjoy seeing white ibises in my neighborhood” | | | |
| Moral duty | Feeding because of a moral duty to do so | “I have a duty to feed white ibises”<br>“I feed white ibises to make up for the damage humans have done to their environment”<br>“I feed white ibises to make up for the damage I have done to their environment”<br>“I feed white ibises because they do not have enough food to eat” | 0.74 ± 0.018 | 1.99 ± 0.58, 0.7, 3.5 | NA |
| Conservation | Feeding to promote conservation | “I feed white ibises so that they increase their numbers in my area”<br>“I feed white ibises so that they stay in my area”<br>“Feeding white ibises is important for their conservation”<br>“Feeding white ibises is important for their survival”<br>“White ibises that live in the cities are important to the environment”<br>“Feeding white ibises makes me feel connected to nature”<br>“I feed white ibises because they do not have enough food to eat”<br>“I have a duty to feed white ibises” | 0.84 ± 0.0085 | 1.95 ± 0.38, 1.01, 2.94 | NA |

| | | | | | |
|---|---|---|---|---|---|
| | | "I feed white ibises to make up for the damage humans have done to their environment"<br>"I feed white ibises to make up for the damage I have done to their environment" | | | |
| Nurturing | Feeding as a means to care for ibises | "I feed white ibises because it makes them happy"<br>"I feed white ibises because they do not have enough to eat"<br>"I have a duty to feed white ibises"<br>"I feed white ibises so that they stay in my area"<br>"I feed white ibises so that they increase their numbers in my area"<br>"Feeding white ibises is important for their survival"<br>"White ibises are friendly birds"<br>"I think of white ibises as my friends"<br>"I think of white ibises as my pets"<br>"I have named white ibises I see regularly" | 0.82 ± 0.0083 | 1.84 ± 0.37, 0.77, 2.9 | NA |
| Companionship | Feeding as a means to get a sense of companionship | "Feeding white ibises makes me feel less lonely"<br>"I get excited when I see white ibises coming back to me for food"<br>"White ibises are friendly birds"<br>"I think of white ibises as my friends"<br>"I think of white ibises as my pets"<br>"I have named white ibises I see regularly"<br>"I feed white ibises so that they stay in my area" | 0.75 ± 0.015 | 1.87 ± 0.37, 0.92, 2.85 | NA |
| Anthropomorphism | Thinking of ibises as friends or pets | "I think of white ibises as my friends"<br>"I think of white ibises as my pets" | 0.68 ± 0.036 | 1.94 ± 0.48, 0.77, 3.22 | 1.55 ± 0.38, |

| | | | | | |
|---|---|---|---|---|---|
| | | "I have named the white ibises I see regularly"<br>"White ibises are friendly birds" | | | 0.65, 2.91 |
| Awareness | Awareness of the impacts of feeding on ibis health, behavior, and ecology | "Feeding white ibises makes them dependent on humans"<br>"Feeding white ibises is harmful to their health"<br>"Feeding white ibises can alter their behavior"<br>"Feeding white ibises can make them more aggressive"<br>"Feeding white ibises is important to their survival"<br>"Feeding white ibises is important for their conservation" | 0.77 ± 0.013 | 1.89 ± 0.37, 0.64, 3.06 | 2.08 ± 0.26, 1.18, 2.90 |
| Risk sensitivity | Concerns about potential nuisance caused by ibises | How concerned are you about the following:<br>"White ibises defecating (pooping) on your property (for example, house, car)"<br>"White ibises defecating (pooping) on paths, picnic tables and other public places"<br>"White ibises transmitting diseases to people"<br>"White ibises transmitting diseases to other wild birds"<br>"White ibises transmitting diseases to pets"<br>"White ibises attacking pets"<br>"White ibises attacking people" | 0.92 ± 0.0088 | 1.93 ± 0.97, 0.80, 4.01 | 1.69 ± 0.85, 0.80, 4.01 |
| Risk susceptibility | Responsibility of feeders for aggravating nuisance caused by ibises | How likely do you think that people who feed white ibises causes white ibises to:<br>"Become aggressive towards humans"<br>"Become aggressive towards other white ibises"<br>"Defecate (poop) on people's property" | 0.89 ± 0.0064 | 1.59 ± 0.66, 0.76, 3.59 | 1.76 ± 0.71, 0.76, 3.79 |

| | | | | | |
|---|---|---|---|---|---|
| | | "Defecate (poop) on paths, picnic tables and other public places"<br>"Transmit diseases to other wild birds"<br>"Transmit diseases to pets"<br>"Transmit diseases to people" | | | |

TABLE 4.3. Comparison of Generalized Linear Models (GLMs) for predicting feeding behavior. The GLMs evaluated the influence of demographic, socioeconomic, and socio-psychological variables on White Ibis feeding behavior. Models were compared based on the Akaike Information Criterion (AIC) values, with lower AIC scores indicating a better model fit. The table details the variables included in each model and the change in AIC (ΔAIC) relative to the best-fit model. This model included all significant variables from our statistical tests comparing feeders and non-feeders. We used a five-point scale for all variables, except binary responses and loneliness score (1-10 scale). Anthropomorphism (tendency for respondents to establish human-like relationships with ibises), awareness (degree to which they were aware of the health and ecological consequences of feeding), risk sensitivity (their concern regarding human-ibis conflicts), and risk susceptibility (whether they believed feeders to be responsible for human-ibis conflicts) were built based on socio-psychological constructs using multiple survey items. Statistical significance was considered at $p \leq 0.05$.

| Model | Variables | AIC | ΔAIC |
|---|---|---|---|
| Statistics | Age ($\beta = -0.03$, $p = 0.001$) + education ($\beta = 0.03$, $p = 0.66$) + income ($\beta = -0.01$, $p = 0.12$) + years lived in FL ($\beta = 0.05$, $p = 0.02$) + county of residence ($\beta = -0.58$, $p = 0.20$) + number of people in household ($\beta = 0.03$, $p = 0.77$) + pets ($\beta = -0.15$, $p = 0.57$) + bird | 449.93 | 0 |

| | | | |
|---|---|---|---|
| | feeder ($\beta = 1.70$, $p < 0.001$) + loneliness score ($\beta = 0.03$, $p = 0.47$) + likes ibises ($\beta = 0.12$, $p = 0.54$) + positive emotions ($\beta = 0.73$, $p = 0.08$) + anthropomorphism ($\beta = 1.80$, $p < 0.001$) + awareness ($\beta = -2.13$, $p < 0.001$ ) + risk sensitivity ($\beta = 0.52$, $p = 0.003$) + risk susceptibility ($\beta = -0.44$, $p = 0.06$) | | |
| Global | Age ($\beta = -0.03$, $p < 0.001$ ) + gender ($\beta = -0.38$, $p = 0.15$) + education ($\beta = 0.03$, $p = 0.63$) + income ($\beta = -0.01$, $p = 0.10$) + resident status in FL ($\beta = 1.39$, $p = 0.10$) + years lived in FL ($\beta = 0.05$, $p = 0.02$) + county of residence ($\beta = -0.60$, $p = 0.18$) + number of people in household ($\beta = 0.03$, $p = 0.75$) + pets ($\beta = -0.21$, $p = 0.44$) + bird feeder ($\beta = 1.78$, $p < 0.001$ ) + loneliness score ($\beta = 0.03$, $p = 0.46$) + ibis population increase ($\beta = -0.06$, $p = 0.74$) + likes ibises ($\beta = 0.12$, $p = 0.55$) + positive emotions ($\beta = 0.67$, $p = 0.11$) + negative emotions ($\beta = -0.08$, $p = 0.94$) + anthropomorphism ($\beta = 1.79$, $p < 0.001$) + awareness ($\beta = -2.13$, $p < 0.001$ ) + risk sensitivity ($\beta = 0.49$, $p = 0.01$) + risk susceptibility ($\beta = -0.45$, $p = 0.07$) | 452.40 | 2.47 |
| Opinions and beliefs | Ibis population increase ($\beta = -0.01$, $p = 0.94$) + likes ibises ($\beta = 0.03$, $p = 0.87$) + positive emotions ($\beta = 0.73$, $p = 0.07$) + negative emotions ($\beta = 0.27$, $p = 0.78$) + | 521.33 | 71.40 |

| | | | |
|---|---|---|---|
| | anthropomorphism ($\beta = 2.21$, $p < 0.001$) + awareness ($\beta = -2.37$, $p < 0.001$ ) + risk sensitivity ($\beta = 0.60$, $p < 0.001$) + risk susceptibility ($\beta = -0.38$, $p = 0.07$) | | |
| Demographics | Age ($\beta = -0.04$, $p < 0.001$ ) + gender ($\beta = -0.71$, $p = 0.002$) + education ($\beta = -0.01$, $p = 0.82$) + income ($\beta = -0.01$, $p = 0.08$) + resident status in FL ($\beta = 1.11$, $p = 0.14$) + years lived in FL ($\beta = 0.05$, $p = 0.01$) + county of residence ($\beta = -0.92$, $p = 0.02$) + number of people in household ($\beta = 0.06$, $p = 0.54$) + pets ($\beta = -0.10$, $p = 0.69$) + bird feeder ($\beta = 1.96$, $p < 0.001$) + loneliness score ($\beta = 0.03$, $p = 0.28$) | 520.86 | 70.93 |
| Null | None | 656.70 | 206.77 |

TABLE 4.4. Coefficients from linear discriminant analyses conducted to differentiate between respondents feeding White Ibises at various frequencies ranging from one (*only occasionally*) to five (*every day*). Four analyses were performed, each focusing on a distinct motivational socio-psychological construct: (1) egocentric motivations and moral duty, (2) conservation support, (3) nurturing intentions, and (4) companionship. The coefficients indicate the relative contribution of each variable to the discriminant functions that best separate feeders based on their feeding frequency.

| | Analysis 1 coefficients | | Analysis 2 coefficients | | Analysis 3 coefficients | | Analysis 4 coefficients | |
|---|---|---|---|---|---|---|---|---|
| Variable | Function 1 (0.46) | Function 2 (0.27) | Function 1 (0.46) | Function 2 (0.27) | Function 1 (0.47) | Function 2 (0.27) | Function 1 (0.45) | Function 2 (0.29) |
| Spending money to feed | 1.67 | -0.19 | 1.78 | -0.66 | 1.81 | -0.59 | 1.84 | -0.47 |
| Anthropomorphism | 1.09 | 0.61 | 1.41 | 0.24 | 1.58 | 0.27 | 1.55 | 2.10 |
| Egocentric motivations | 1.09 | -1.38 | NA | NA | NA | NA | NA | NA |
| Getting a sense of companionship | NA | NA | NA | NA | NA | NA | -0.50 | -3.08 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Feeding at the beach | -0.24 | -1.18 | -0.32 | -1.15 | -0.30 | -1.16 | -0.36 | -1.07 |
| Feeding pet food | -0.24 | 1.45 | -0.01 | 1.41 | 0.03 | 1.51 | 0.13 | 1.56 |
| Feeding nuts | 0.65 | -1.51 | 0.28 | -1.44 | 0.33 | -1.40 | 0.28 | -1.47 |

NA: Not applicable.

FIGURES

FIGURE 4.1. White Ibises feeding on provisioned food at an urban park in Palm Beach County, Florida.

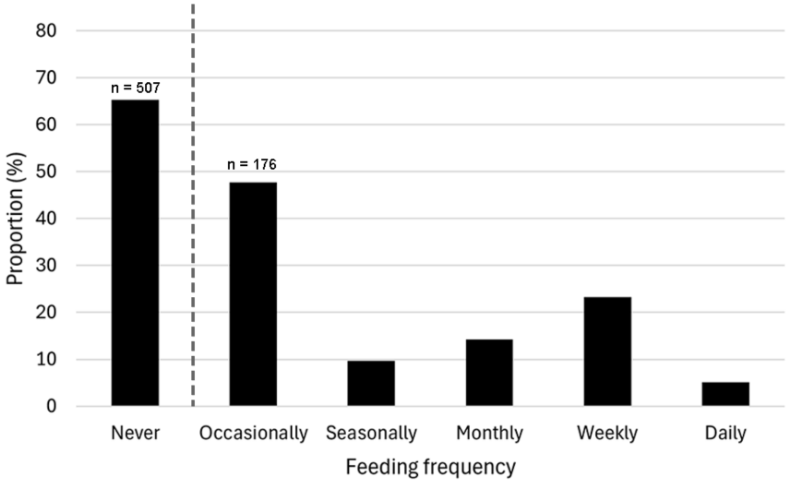

FIGURE 4.2. Frequencies at which residents of south Florida feed White Ibises. The dotted line separates non-feeders and feeders. Non-feeder proportion was extracted from the total sample size (n = 507), while feeder proportions were computed based on the total number of respondents who engage in feeding (n = 176).

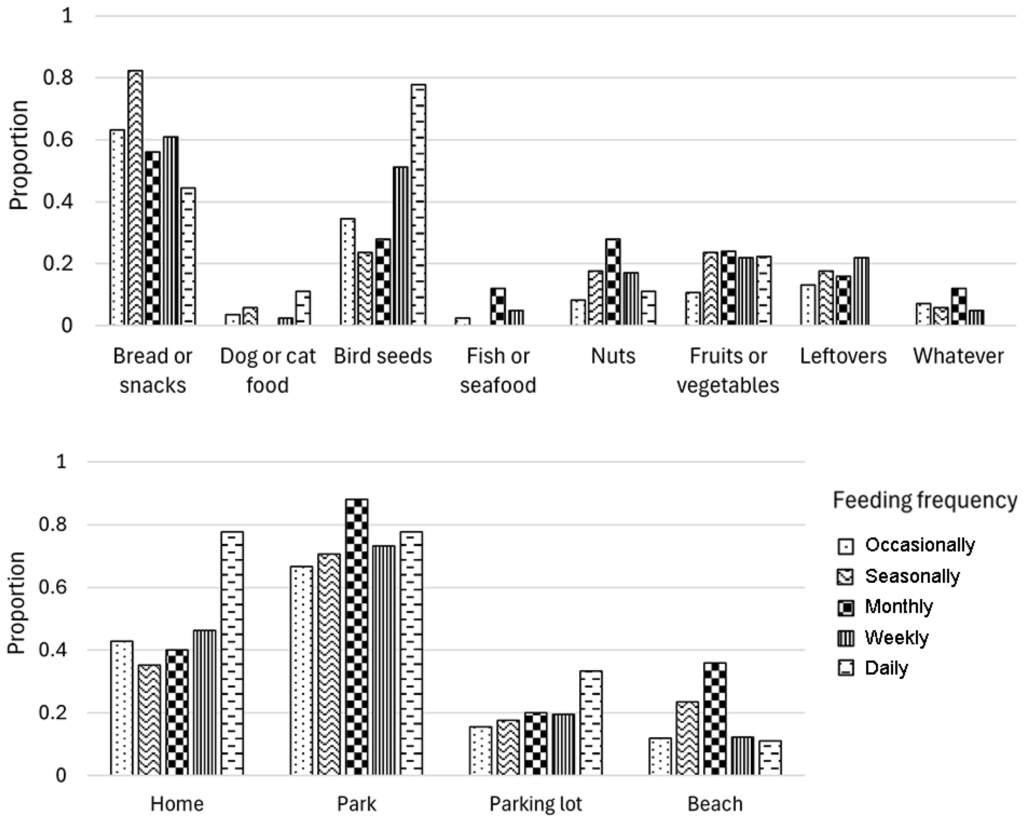

FIGURE 4.3. Distribution of feeding locations and food types provided to White Ibises by feeding frequency. Food types include bread or snacks, such as chips, bird seeds, pet food, fish or seafood (ibises’ natural prey), nuts, fruits or vegetables, leftovers, and "*whatever I have in my pocket*". Locations include home, urban parks, parking lots, and beaches.

# APPENDICES

TABLE S1. Sociodemographic information reported by respondents (n=507) who feed (“feeders”, n=176) and do not feed (“non-feeders”, n=331) White Ibises in south Florida as reported by an online survey deployed in 2024.

| Category | Total respondents, n (%) | Feeders, n (%) | Non-feeders, n (%) |
|---|---|---|---|
| **Age** | | | |
| 18-24 years | 37 (7.30) | 21 (11.9) | 37 (11.2) |
| 25-34 years | 47 (9.27) | 27 (15.3) | 47 (14.2) |
| 35-44 years | 85 (16.8) | 44 (25.5) | 85 (25.7) |
| 45-54 years | 57 (11.2) | 17 (9.66) | 57 (17.2) |
| 55-64 years | 95 (18.7) | 34 (19.3) | 95 (28.7) |
| 65-74 years | 111 (21.9) | 17 (9.66) | 111 (33.5) |
| 75+ years | 75 (14.9) | 16 (9.09) | 75 (22.7) |
| **Gender** | | | |
| Male | 187 (36.9) | 74 (42.5) | 114 (34.4) |
| Female | 318 (62.7) | 102 (58.0) | 217 (65.6) |
| Non-binary | 2 (0.39) | 1 (0.57) | 1 (0.30) |
| Prefer not to say | 0 (0.00) | 0 (0.00) | 0 (0.00) |
| **Residency status in Florida** | | | |
| Seasonal | 19 (3.75) | 3 (1.70) | 16 (4.83) |
| Year-round | 488 (96.3) | 173 (98.3) | 315 (95.2) |
| **County of residence** | | | |
| Martin | 56 (11.0) | 12 (6.82) | 44 (13.3) |
| Palm Beach | 451 (89.0) | 164 (93.2) | 287 (86.7) |
| **Years residing in Florida** | | | |
| < 1 year | 9 (1.78) | 2 (1.14) | 7 (2.11) |
| 1-5 years | 43 (8.48) | 9 (5.11) | 34 (10.3) |
| 6-10 years | 67 (13.2) | 18 (10.2) | 49 (14.8) |
| 11-20 years | 83 (16.4) | 26 (14.8) | 57 (17.2) |
| Over 20 years | 305 (60.2) | 121 (68.8) | 184 (55.6) |
| **Education level** | | | |
| Less than 12th grade | 10 (1.97) | 3 (1.70) | 7 (2.11) |
| High school graduate or GED | 91 (17.9) | 47 (26.7) | 44 (13.3) |
| Some college/associate or technical degree | 167 (32.9) | 60 (34.1) | 107 (32.3) |

| | | | |
|---|---|---|---|
| Bachelor's degree | 152 (30.0) | 43 (24.4) | 109 (32.9) |
| Graduate or professional degree | 87 (17.2) | 23 (13.1) | 64 (19.3) |
| **Household income before taxes** | | | |
| $25,000 or less | 65 (12.8) | 25 (14.2) | 40 (12.1) |
| $25,001-50,000 | 108 (21.3) | 42 (23.9) | 66 (19.9) |
| $50,001-75,000 | 102 (20.1) | 37 (21.0) | 65 (19.6) |
| $75,001-100,000 | 77 (15.2) | 24 (13.6) | 53 (16.0) |
| $100,001 or more | 134 (26.4) | 37 (21.0) | 97 (29.3) |
| Prefer not to say | 15 (2.96) | 5 (2.84) | 10 (3.02) |
| **People living in household including oneself** | | | |
| 1 ("I live by myself") | 125 (24.7) | 36 (20.5) | 89 (26.9) |
| 2 | 224 (44.2) | 63 (35.8) | 161 (48.6) |
| 3-5 | 138 (27.2) | 68 (38.6) | 70 (21.2) |
| 6 or more people | 20 (3.94) | 9 (5.11) | 11 (3.32) |
| **Have children living in household** | 120 (23.7) | 61 (34.7) | 59 (17.8) |
| **Pet ownership** | 310 (61.1) | 144 (81.8) | 166 (50.2) |
| Dogs | 205 (40.4) | 87 (49.4) | 118 (35.6) |
| Cats | 130 (25.6) | 60 (34.1) | 70 (21.1) |
| Fish | 24 (4.73) | 14 (7.95) | 10 (3.02) |
| Birds | 25 (4.96) | 18 (10.2) | 7 (2.11) |
| Other mammals | 15 (2.96) | 8 (4.55) | 7 (2.11) |
| Reptiles | 19 (3.75) | 10 (5.68) | 9 (2.72) |
| Amphibians | 3 (0.59) | 2 (1.14) | 1 (0.30) |
| Insects and/or arachnids | 1 (0.20) | 0 (0.00) | 1 (0.30) |
| Other | 1 (0.20) | 0 (0.00) | 1 (0.30) |
| **Uses bird feeder** | 121 (23.9) | 80 (45.5) | 41 (12.4) |
| Every day | 66 (13.0) | 48 (27.3) | 18 (5.44) |
| At least once every week | 43 (8.48) | 30 (17.1) | 13 (3.93) |
| At least once every month | 3 (0.59) | 1 (0.57) | 2 (0.60) |
| Seasonally | 4 (0.79) | 0 (0.00) | 4 (1.21) |
| Only occasionally | 5 (0.99) | 1 (0.57) | 4 (1.21) |
| Never | 386 (76.1) | 96 (54.6) | 290 (87.6) |
| **Frequency at which feels lonely** | | | |
| 0 ("I never feel lonely") | 80 (15.8) | 20 (11.4) | 60 (18.1) |
| 1 | 75 (14.8) | 24 (13.6) | 51 (15.4) |
| 2 | 70 (13.8) | 13 (7.39) | 57 (17.2) |
| 3 | 67 (13.2) | 26 (14.8) | 41 (12.4) |
| 4 | 45 (8.88) | 21 (11.9) | 24 (7.25) |
| 5 | 53 (10.5) | 17 (9.66) | 36 (10.9) |
| 6 | 29 (5.72) | 11 (6.25) | 18 (5.44) |

| | | | |
|---|---|---|---|
| 7 | 36 (7.10) | 17 (9.66) | 19 (5.74) |
| 8 | 18 (3.55) | 6 (3.41) | 12 (3.63) |
| 9 | 15 (2.96) | 10 (5.68) | 5 (1.51) |
| 10 (“I always feel lonely”) | 19 (3.75) | 11 (6.25) | 8 (2.42) |

TABLE S2. Opinions about White Ibises reported by residents of south Florida who feed (n=176) and do not feed (n=331) these birds.

| Question | Total respondents, n (%) | Feeders, n (%) | Non-feeders, n (%) |
|---|---|---|---|
| **Do you like or dislike white ibises?** | | | |
| Strongly dislike | 0 (0.00) | 0 (0.00) | 0 (0.00) |
| Dislike | 9 (1.78) | 3 (1.70) | 6 (1.81) |
| Neither like nor dislike | 103 (20.3) | 22 (12.5) | 81 (24.5) |
| Like | 222 (43.8) | 82 (46.6) | 140 (42.3) |
| Strongly like | 173 (34.1) | 69 (39.2) | 104 (31.4) |
| **What emotions do you feel when you see white ibises? Select all that apply.** | | | |
| Joy | 242 (47.7) | 90 (51.1) | 152 (45.9) |
| Excitement | 97 (19.1) | 52 (29.5) | 45 (13.6) |
| Calm | 291 (57.4) | 107 (60.8) | 184 (55.6) |
| Love | 129 (25.4) | 71 (40.3) | 58 (17.5) |
| Sadness | 4 (0.79) | 1 (0.57) | 3 (1.70) |
| Anger | 1 (0.20) | 1 (0.57) | 0 (0.00) |
| Disgust | 1 (0.20) | 0 (0.00) | 1 (0.30) |
| Irritation | 5 (1.00) | 1 (0.57) | 4 (1.21) |
| Fear | 4 (0.79) | 1 (0.57) | 3 (0.91) |
| I don’t feel any emotion | 68 (13.4) | 12 (6.82) | 56 (16.9) |
| **I would like the population of white ibises in my area to:** | | | |
| Decrease a large amount | 8 (1.58) | 2 (1.14) | 6 (1.81) |
| Decrease a small amount | 21 (4.14) | 9 (5.11) | 12 (3.63) |
| Stay the same | 352 (69.4) | 115 (65.3) | 237 (71.6) |
| Increase a small amount | 87 (17.2) | 30 (17.1) | 57 (17.2) |
| Increase a large amount | 78 (15.4) | 40 (22.7) | 38 (11.5) |

TABLE S3. Responses from residents of south Florida who feed (n=176) and do not feed (n=331) White Ibises to statements that anthropomorphize ibises and to those that highlight the impacts of supplementary feeding on ibis ecology, health, and behavior. Respondents were asked whether they agreed or disagreed with various statements.

| Statement | Total respondents, n (%) | Feeders, n (%) | Non-feeders, n (%) |
|---|---|---|---|
| **Anthropomorphism** | | | |
| White ibises are friendly birds | | | |
| Strongly disagree | 6 (1.18) | 1 (0.57) | 5 (1.51) |
| Disagree | 30 (5.92) | 8 (4.55) | 22 (6.65) |
| Neither agree nor disagree | 226 (44.6) | 45 (25.6) | 181 (54.7) |
| Agree | 191 (37.7) | 88 (50.0) | 103 (31.1) |
| Strongly agree | 54 (10.7) | 34 (19.3) | 20 (6.04) |
| I think of white ibises as my friends | | | |
| Strongly disagree | 32 (6.31) | 5 (2.84) | 27 (8.16) |
| Disagree | 107 (21.1) | 30 (17.1) | 77 (23.3) |
| Neither agree nor disagree | 203 (40.0) | 57 (32.4) | 146 (44.1) |
| Agree | 130 (25.6) | 60 (34.1) | 70 (21.2) |
| Strongly agree | 35 (6.90) | 24 (13.6) | 11 (3.32) |
| I think of white ibises as my pets | | | |
| Strongly disagree | 146 (28.8) | 24 (13.6) | 122 (36.9) |
| Disagree | 217 (42.8) | 79 (44.9) | 138 (41.7) |
| Neither agree nor disagree | 111 (21.9) | 44 (25.0) | 67 (20.2) |
| Agree | 22 (4.34) | 19 (10.8) | 3 (0.91) |
| Strongly agree | 11 (2.17) | 10 (5.68) | 1 (0.30) |
| I have named white ibises I see regularly | | | |
| Strongly disagree | 174 (34.3) | 29 (16.5) | 145 (43.8) |
| Disagree | 201 (39.6) | 70 (39.8) | 131 (39.6) |
| Neither agree nor disagree | 90 (17.8) | 44 (25.0) | 46 (13.9) |
| Agree | 29 (5.72) | 22 (12.5) | 7 (2.11) |
| Strongly agree | 13 (2.56) | 11 (6.25) | 2 (0.60) |
| **Awareness** | | | |
| Feeding white ibises makes them dependent on humans | | | |
| Strongly disagree | 9 (1.78) | 9 (5.11) | 0 (0.00) |
| Disagree | 56 (11.1) | 38 (21.6) | 18 (5.44) |
| Neither agree nor disagree | 156 (30.8) | 71 (40.3) | 85 (25.7) |
| Agree | 208 (41.0) | 46 (26.1) | 162 (48.9) |

| | | | |
|---|---|---|---|
| Strongly agree | 78 (15.4) | 12 (6.82) | 66 (19.9) |
| Feeding white ibises can alter their behavior | | | |
| Strongly disagree | 8 (1.58) | 8 (4.55) | 0 (0.00) |
| Disagree | 40 (7.89) | 29 (16.5) | 11 (3.32) |
| Neither agree nor disagree | 177 (34.9) | 76 (43.2) | 101 (30.5) |
| Agree | 220 (43.4) | 53 (30.1) | 167 (50.5) |
| Strongly agree | 62 (12.2) | 10 (5.68) | 52 (15.7) |
| Feeding white ibises can make them more aggressive | | | |
| Strongly disagree | 41 (8.09) | 29 (16.5) | 12 (3.63) |
| Disagree | 103 (20.3) | 60 (34.1) | 43 (13.0) |
| Neither agree nor disagree | 247 (48.7) | 59 (33.5) | 188 (56.8) |
| Agree | 84 (16.6) | 24 (13.6) | 60 (18.1) |
| Strongly agree | 32 (6.31) | 4 (2.27) | 28 (8.46) |
| Feeding white ibises is harmful to their health | | | |
| Strongly disagree | 28 (5.52) | 23 (13.1) | 5 (1.51) |
| Disagree | 77 (15.2) | 57 (32.4) | 20 (6.04) |
| Neither agree nor disagree | 227 (44.8) | 71 (40.3) | 156 (47.1) |
| Agree | 125 (24.7) | 20 (11.4) | 105 (31.7) |
| Strongly agree | 50 (9.86) | 5 (2.84) | 45 (13.6) |
| Feeding white ibises is important to their survival | | | |
| Strongly disagree | 54 (10.7) | 9 (5.11) | 45 (13.6) |
| Disagree | 143 (28.2) | 28 (15.9) | 115 (34.7) |
| Neither agree nor disagree | 215 (42.4) | 67 (38.1) | 148 (44.7) |
| Agree | 70 (13.8) | 52 (29.6) | 18 (5.44) |
| Strongly agree | 25 (4.93) | 20 (11.4) | 5 (1.51) |
| Feeding white ibises is important for their conservation | | | |
| Strongly disagree | 56 (11.1) | 11 (6.25) | 45 (13.6) |
| Disagree | 117 (23.1) | 24 (13.6) | 93 (28.1) |
| Neither agree nor disagree | 230 (45.4) | 62 (35.2) | 168 (50.8) |
| Agree | 85 (16.8) | 61 (34.7) | 24 (7.25) |
| Strongly agree | 19 (3.75) | 18 (10.2) | 1 (0.30) |

TABLE S4. Risk sensitivity of south Florida residents to nuisances caused by White Ibises depending on whether they reported to feed (n=176) or not feed (n=331) ibises. Respondents answered the question: “How concerned are you about…”

| Statement | Total respondents, n (%) | Feeders, n (%) | Non-feeders, n (%) |
|---|---|---|---|
| **White ibises defecating (pooping) on paths, picnic tables and other public places** | | | |
| Strongly disagree | 173 (34.1) | 54 (30.7) | 119 (36.0) |
| Disagree | 152 (30.0) | 48 (27.3) | 104 (31.4) |
| Neither agree nor disagree | 97 (19.1) | 34 (19.3) | 63 (19.0) |
| Agree | 60 (11.8) | 26 (14.8) | 34 (10.3) |
| Strongly agree | 25 (4.93) | 14 (7.95) | 11 (3.32) |
| **White ibises defecating (pooping) on your property (for example, house, car)** | | | |
| Strongly disagree | 189 (37.3) | 65 (36.9) | 124 (37.5) |
| Disagree | 131 (25.8) | 36 (20.5) | 95 (28.7) |
| Neither agree nor disagree | 73 (14.4) | 28 (15.9) | 45 (13.6) |
| Agree | 73 (14.4) | 26 (14.8) | 47 (14.2) |
| Strongly agree | 41 (8.09) | 21 (11.9) | 20 (6.04) |
| **White ibises transmitting diseases to other wild birds** | | | |
| Strongly disagree | 191 (37.7) | 54 (30.7) | 137 (41.4) |
| Disagree | 117 (23.1) | 40 (22.7) | 77 (23.3) |
| Neither agree nor disagree | 115 (22.7) | 43 (24.4) | 72 (21.8) |
| Agree | 58 (11.4) | 24 (13.6) | 34 (10.3) |
| Strongly agree | 26 (5.13) | 15 (8.52) | 11 (3.32) |
| **White ibises transmitting diseases to pets** | | | |
| Strongly disagree | 200 (39.5) | 63 (35.8) | 137 (41.4) |
| Disagree | 114 (22.5) | 36 (20.5) | 78 (23.6) |
| Neither agree nor disagree | 86 (17.0) | 31 (17.6) | 55 (16.6) |
| Agree | 59 (11.6) | 23 (13.1) | 36 (10.9) |
| Strongly agree | 48 (9.47) | 23 (13.1) | 25 (7.55) |
| **White ibises transmitting diseases to people** | | | |
| Strongly disagree | 220 (43.4) | 66 (37.5) | 154 (46.5) |
| Disagree | 94 (18.5) | 32 (18.2) | 62 (18.7) |
| Neither agree nor disagree | 70 (13.8) | 29 (16.5) | 41 (12.4) |

| | | | |
|---|---|---|---|
| Agree | 56 (11.1) | 20 (11.4) | 36 (10.9) |
| Strongly agree | 67 (13.2) | 29 (16.5) | 38 (11.5) |
| **White ibises attacking pets** | | | |
| Strongly disagree | 260 (51.3) | 82 (46.6) | 178 (53.8) |
| Disagree | 88 (17.4) | 27 (15.3) | 61 (18.4) |
| Neither agree nor disagree | 63 (12.4) | 23 (13.1) | 40 (12.1) |
| Agree | 46 (9.07) | 19 (10.8) | 27 (8.16) |
| Strongly agree | 50 (9.86) | 25 (14.2) | 25 (7.55) |
| **White ibises attacking people** | | | |
| Strongly disagree | 283 (55.8) | 89 (50.6) | 194 (58.6) |
| Disagree | 79 (15.6) | 26 (14.8) | 53 (16.0) |
| Neither agree nor disagree | 51 (10.1) | 21 (11.9) | 30 (9.06) |
| Agree | 39 (7.69) | 15 (8.52) | 24 (7.25) |
| Strongly agree | 55 (10.9) | 25 (14.2) | 30 (9.06) |

TABLE S5. Risk susceptibility of south Florida residents to nuisances caused by White Ibises depending on whether they reported to feed (n=176) or not feed (n=331) ibises. Respondents answered the question: “How likely do you think feeding causes White Ibises to…”

| Statement | Total respondents, n (%) | Feeders, n (%) | Non-feeders, n (%) |
|---|---|---|---|
| **Become aggressive towards other white ibises** | | | |
| Strongly disagree | 198 (39.1) | 84 (47.7) | 114 (34.4) |
| Disagree | 137 (27.0) | 47 (26.7) | 90 (27.2) |
| Neither agree nor disagree | 106 (20.9) | 29 (16.5) | 77 (23.3) |
| Agree | 45 (8.88) | 12 (6.82) | 33 (9.97) |
| Strongly agree | 21 (4.14) | 4 (2.27) | 17 (5.14) |
| **Become aggressive towards humans** | | | |
| Strongly disagree | 229 (45.2) | 98 (55.7) | 131 (39.6) |
| Disagree | 137 (27.0) | 48 (27.3) | 89 (26.9) |
| Neither agree nor disagree | 76 (15.0) | 20 (11.4) | 56 (16.9) |
| Agree | 46 (9.07) | 10 (5.68) | 36 (10.9) |
| Strongly agree | 19 (3.75) | 0 (0.00) | 19 (5.74) |
| **Defecate (poop) on paths, picnic tables and other public places** | | | |
| Strongly disagree | 85 (16.8) | 35 (19.9) | 50 (15.1) |
| Disagree | 130 (25.6) | 51 (29.0) | 79 (23.9) |
| Neither agree nor disagree | 134 (26.4) | 44 (25.0) | 90 (27.2) |
| Agree | 101 (19.9) | 27 (15.3) | 74 (22.4) |

| | | | |
|---|---|---|---|
| Strongly agree | 57 (11.2) | 19 (10.8) | 38 (11.5) |
| **Defecate (poop) on people’s property** | | | |
| Strongly disagree | 88 (17.4) | 36 (20.5) | 52 (15.7) |
| Disagree | 131 (25.8) | 53 (30.1) | 78 (23.6) |
| Neither agree nor disagree | 120 (23.7) | 39 (22.2) | 81 (24.5) |
| Agree | 109 (21.5) | 30 (17.1) | 79 (23.9) |
| Strongly agree | 59 (11.6) | 18 (10.2) | 41 (12.4) |
| **Transmit diseases to other wild birds** | | | |
| Strongly disagree | 198 (39.1) | 77 (43.8) | 121 (36.6) |
| Disagree | 145 (28.6) | 50 (28.4) | 95 (28.7) |
| Neither agree nor disagree | 109 (21.5) | 30 (17.1) | 79 (23.9) |
| Agree | 40 (7.89) | 14 (7.95) | 26 (7.85) |
| Strongly agree | 15 (2.96) | 5 (2.84) | 10 (3.02) |
| **Transmit diseases to pets** | | | |
| Strongly disagree | 220 (43.4) | 86 (48.9) | 134 (40.5) |
| Disagree | 138 (27.2) | 42 (23.9) | 96 (29.0) |
| Neither agree nor disagree | 90 (17.8) | 28 (15.9) | 62 (18.7) |
| Agree | 42 (8.28) | 15 (8.52) | 27 (8.16) |
| Strongly agree | 17 (3.35) | 5 (2.84) | 12 (3.63) |
| **Transmit diseases to people** | | | |
| Strongly disagree | 241 (47.5) | 86 (48.9) | 155 (46.8) |
| Disagree | 138 (27.2) | 44 (25.0) | 94 (28.4) |
| Neither agree nor disagree | 77 (15.2) | 30 (17.1) | 47 (14.2) |
| Agree | 32 (6.31) | 11 (6.25) | 21 (6.34) |
| Strongly agree | 19 (3.75) | 5 (2.84) | 14 (4.23) |

TABLE S6. Responses from residents of south Florida (n=176) who feed White Ibises to various questions regarding feeding activity.

| Category | Responses, n (%) |
|---|---|
| **Feeding frequency** | |
| Every day | 9 (5.11) |
| At least once a week | 41 (23.3) |
| At least once a month | 25 (14.2) |
| Seasonally | 17 (9.66) |
| Only occasionally | 84 (47.7) |
| **Feeding location** | |
| Home | 78 (44.3) |
| Urban parks | 127 (72.2) |
| Beach | 32 (18.2) |

| | |
|---|---|
| Parking lots | 29 (16.5) |
| Other | 2 (1.14) |
| **Food items provided** | |
| Bread or snacks (e.g., chips, cookies) | 110 (62.5) |
| Fruits or vegetables | 30 (17.1) |
| Nuts | 25 (14.2) |
| Bird seed | 68 (38.6) |
| Dog or cat food | 6 (3.41) |
| Fish or seafood | 7 (3.98) |
| Leftovers | 27 (15.3) |
| "Whatever I have in my bag/pocket" | 12 (6.82) |
| Other | 2 (1.14) |
| **Financially invests in feeding** | 41 (23.3) |

TABLE S7. Motivations of residents of south Florida (n=176) to feed White Ibises. Respondents were asked whether they agreed or disagreed with various statements.

| Statement | Strongly disagree, n (%) | Disagree, n (%) | Neither agree nor disagree, n (%) | Agree, n (%) | Strongly agree, n (%) | Factor loading |
|---|---|---|---|---|---|---|
| **Egocentric** | | | | | | |
| Feeding white ibises makes me feel connected to nature | 49 (27.8) | 92 (52.3) | 30 (17.1) | 3 (1.70) | 2 (1.14) | 0.67 |
| Feeding white ibises gives me pleasure | 54 (30.7) | 100 (56.8) | 20 (11.4) | 2 (1.14) | 1 (0.57) | 0.71 |
| Feeding white ibises makes me feel less lonely | 34 (19.3) | 58 (33.0) | 61 (34.7) | 17 (9.66) | 6 (3.41) | 0.60 |
| Feeding white ibises is a stress reliever | 34 (19.3) | 97 (55.1) | 33 (18.8) | 8 (4.55) | 4 (2.27) | 0.73 |
| Feeding white ibises is part of my identity | 21 (11.9) | 25 (14.2) | 83 (47.2) | 32 (18.2) | 15 (8.52) | 0.56 |
| I feed white ibises because it makes them happy | 45 (25.6) | 98 (55.7) | 27 (15.3) | 3 (1.70) | 3 (1.70) | 0.61 |
| I get excited when I see white | 41 (23.3) | 91 (51.7) | 34 (19.3) | 8 (4.55) | 2 (1.14) | 0.67 |

| | | | | | | |
|---|---|---|---|---|---|---|
| ibises coming back to me for food | | | | | | |
| I feed white ibises so that they stay in my area | 25 (14.2) | 74 (42.1) | 56 (31.8) | 14 (7.95) | 7 (3.98) | 0.52 |
| I enjoy seeing white ibises in my neighborhood | 73 (41.5) | 79 (44.9) | 22 (12.5) | 1 (0.57) | 1 (0.57) | 0.55 |
| **Moral duty** | | | | | | |
| I feed white ibises because they do not have enough food to eat | 10 (5.68) | 55 (31.3) | 66 (37.5) | 34 (19.3) | 11 (6.25) | 0.67 |
| I have a duty to feed white ibises | 3 (1.70) | 28 (15.9) | 71 (40.3) | 50 (28.4) | 24 (13.6) | 0.77 |
| I feed white ibises to make up for the damage humans have done to their environment | 16 (9.09) | 59 (33.5) | 55 (31.3) | 25 (14.2) | 21 (11.9) | 0.73 |
| I feed white ibises to make up for the damage I have done to their environment | 8 (4.55) | 24 (13.6) | 59 (33.5) | 41 (23.3) | 44 (25.0) | 0.63 |
| **Conservation** | | | | | | |
| White ibises that live in the cities are important to the environment | 56 (31.8) | 84 (47.7) | 32 (18.2) | 3 (1.70) | 1 (0.57) | 0.45 |
| White ibises that live in the cities should be protected | 86 (48.9) | 74 (42.1) | 8 (4.55) | 7 (3.98) | 1 (0.57) | 0.44 |
| Feeding white ibises makes me feel connected to nature | 49 (27.8) | 92 (52.3) | 30 (17.1) | 3 (1.70) | 2 (1.14) | 0.48 |

| | | | | | | |
|---|---|---|---|---|---|---|
| I feed white ibises because they do not have enough food to eat | 10 (5.68) | 55 (31.3) | 66 (37.5) | 34 (19.3) | 11 (6.25) | 0.55 |
| I have a duty to feed white ibises | 3 (1.70) | 28 (15.9) | 71 (40.3) | 50 (28.4) | 24 (13.6) | 0.69 |
| I feed white ibises to make up for the damage humans have done to their environment | 16 (9.09) | 59 (33.5) | 55 (31.3) | 25 (14.2) | 21 (11.9) | 0.66 |
| I feed white ibises to make up for the damage I have done to their environment | 8 (4.55) | 24 (13.6) | 59 (33.5) | 41 (23.3) | 44 (25.0) | 0.47 |
| I feed white ibises so that they stay in my area | 25 (14.2) | 74 (42.1) | 56 (31.8) | 14 (7.95) | 7 (3.98) | 0.59 |
| I feed white ibises so that they increase their numbers in my area | 16 (9.09) | 40 (22.7) | 85 (48.3) | 24 (13.6) | 11 (6.25) | 0.68 |
| Feeding white ibises is important for their survival | 9 (5.11) | 28 (15.9) | 67 (38.1) | 52 (29.6) | 20 (11.4) | 0.68 |
| Feeding white ibises is important for their conservation | 11 (6.25) | 24 (13.6) | 62 (35.2) | 61 (34.7) | 18 (10.2) | 0.78 |
| **Nurture** | | | | | | |
| I feed white ibises because they do not have enough food to eat | 10 (5.68) | 55 (31.3) | 66 (37.5) | 34 (19.3) | 11 (6.25) | 0.52 |
| I have a duty to feed white ibises | 3 (1.70) | 28 (15.9) | 71 (40.3) | 50 (28.4) | 24 (13.6) | 0.67 |

| | | | | | | |
|---|---|---|---|---|---|---|
| I feed white ibises because it makes them happy | 45 (25.6) | 98 (55.7) | 27 (15.3) | 3 (1.70) | 3 (1.70) | 0.51 |
| I feed white ibises so that they stay in my area | 25 (14.2) | 74 (42.1) | 56 (31.8) | 14 (7.95) | 7 (3.98) | 0.62 |
| I feed white ibises so that they increase their numbers in my area | 16 (9.09) | 40 (22.7) | 85 (48.3) | 24 (13.6) | 11 (6.25) | 0.66 |
| Feeding white ibises is important for their survival | 9 (5.11) | 28 (15.9) | 67 (38.1) | 52 (29.6) | 20 (11.4) | 0.61 |
| White ibises are friendly birds | 1 (0.57) | 8 (4.55) | 45 (25.6) | 88 (50.0) | 34 (19.3) | 0.41 |
| I think of white ibises as my friends | 5 (2.84) | 30 (17.1) | 57 (32.4) | 60 (34.1) | 24 (13.6) | 0.66 |
| I think of white ibises as my pets | 24 (13.6) | 79 (44.9) | 44 (25.0) | 19 (10.8) | 10 (5.68) | 0.63 |
| I have named white ibises I see regularly | 29 (16.5) | 70 (39.8) | 44 (25.0) | 22 (12.5) | 11 (6.25) | 0.53 |
| **Companionship** | | | | | | |
| Feeding white ibises makes me feel less lonely | 34 (19.3) | 58 (33.0) | 61 (34.7) | 17 (9.66) | 6 (3.41) | 0.51 |
| White ibises are friendly birds | 1 (0.57) | 8 (4.55) | 45 (25.6) | 88 (50.0) | 34 (19.3) | 0.45 |
| I think of white ibises as my friends | 5 (2.84) | 30 (17.1) | 57 (32.4) | 60 (34.1) | 24 (13.6) | 0.76 |
| I think of white ibises as my pets | 24 (13.6) | 79 (44.9) | 44 (25.0) | 19 (10.8) | 10 (5.68) | 0.65 |
| I have named white ibises I see regularly | 29 (16.5) | 70 (39.8) | 44 (25.0) | 22 (12.5) | 11 (6.25) | 0.58 |
| I feed white ibises so that they stay in my area | 25 (14.2) | 74 (42.1) | 56 (31.8) | 14 (7.95) | 7 (3.98) | 0.52 |

| | | | | | | |
|---|---|---|---|---|---|---|
| I get excited when I see white ibises coming back to me for food | 41 (23.3) | 91 (51.7) | 34 (19.3) | 8 (4.55) | 2 (1.14) | 0.51 |

TABLE S8. Responses from participants who do not feed White Ibises to various statements on reasons for not engaging in the activity.

| Statement | Strongly disagree, n (%) | Disagree, n (%) | Neither agree nor disagree, n (%) | Agree, n (%) | Strongly agree, n (%) |
|---|---|---|---|---|---|
| I am not interested in feeding white ibises | 92 (27.8) | 105 (31.7) | 104 (31.4) | 22 (6.65) | 8 (2.42) |
| There is sufficient food available in the environment. White ibises don't need my help | 69 (20.9) | 137 (41.4) | 107 (32.3) | 16 (4.83) | 2 (0.60) |
| There are enough people who feed white ibises, so I don't need to | 15 (4.53) | 45 (13.6) | 233 (70.4) | 26 (7.85) | 12 (3.63) |
| I do not feed white ibises because I was told not to feed them (example: "do not feed wildlife" signs) | 67 (20.2) | 104 (31.4) | 98 (29.6) | 46 (13.9) | 16 (4.83) |