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Introduced birds of Saudi Arabia: Status and potential impacts

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ABSTRACT

Introduced species can have devastating impacts on the environment and economy in non-native ranges. In the Kingdom of Saudi Arabia, published knowledge of introduced fauna or flora is very limited, although this knowledge is basic for their management. Thus, this research provides the very first detailed list of invasive bird species in the Kingdom based on intensive field work, citizen science and published literature. The introduced bird community in the Kingdom consists of 21 species, many of which are widely spread across the Kingdom. Distribution of introduced species varies among provinces; the highest numbers are recorded in Riyadh and Eastern Province with 18 species each, representing 9 and 10 families, respectively. A few of the reported species are linked with devastating ecological and economic impacts in introductions that took place elsewhere, such as Indian House Crow, Common Myna, and Red-vented bulbul. Harvest of wild birds for the purpose of pet trade caused the introduction of three known natives of the highlands in the south-west region into the deserts of the Central and Eastern region. It is evident that the Kingdom harbors many introduced species that are invasive and are known of having a wide range of impacts, necessitating further studies to provide management insights. Management actions directed by these scientific findings is crucially needed to prevent future introductions and contain previously established ones.

1. Introduction

One of the globally pressing environmental issues is the introduction of fauna and flora into novel habitats (Blackburn et al., 2019; Pyšek et al., 2020). Realizing that not all introductions are benign, the science of biological invasion was founded by Charles Elton's seminal work in 1958 (Davis et al., 2001). Invasive species describes any species, flora or fauna, introduced intentionally or accidently beyond its native range and established to cause adverse impacts (Clavero et al., 2009; Courchamp et al., 2017). A multitude of invasive species are known for invading several continents and wreaking havoc, both ecologically and economically, in the invaded ecosystems (Lowe et al., 2000). Ecologically, these prolific species, mostly opportunistic generalists, are homogenizing community structure across the world (Clavero et al., 2009). Their impact varies from changing the structure and functions of ecosystems to altering community and habitat composition (Martin-Albarracin et al., 2015; Pejchar and Mooney, 2009; Simberloff et al., 2013). Therefore, invasive species are considered a major threat that has caused biodiversity loss and changed ecosystem functions at unprecedented levels (Didham et al., 2005; Magory Cohen et al., 2019; Pejchar and Mooney, 2009). Economically, invasive species are impacting infrastructure and economic activities causing a significant monetary loss (Pimentel et al., 2005). Given the ecological and economic costs associated with biological invasion, scientific research dedicated towards studying the dynamics of species invasion is warranted. Such research would help elucidate aspects such as source of introduction, drivers of establish-

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ment and impact on recipient communities, with an ultimate goal of preventing future introductions and containing and eradicating previous ones (McGeoch et al., 2016).

Birds are one of the first animals to be transferred and introduced beyond their natural ranges (Lever, 2005). Introduction of birds is driven primarily by sporting, aesthetic, food and conservation purposes (Blackburn et al., 2015; Lever, 2005). Cultural and religious practices in certain parts of the world have also facilitated bird introductions (Blackburn et al., 2015). Among all documented bird introductions, pet trade is the primary driver globally (Blackburn et al., 2015). Likewise, the first documented bird introduction in the Arabian Peninsula was the Ring-necked Parakeet, an escapee on its route to Britain for the purpose of sale (Jennings, 2010). In the 21th century, bird introductions driven by cage escapees increased, underscoring the need for laws regulating pet trade (Brochet et al., 2019; Carpio et al., 2020). One of the major efforts was the European Union ban on the trade of wild-caught birds, which resulted in a significant reduction in the number of new invasions. Consequently, trade of wild-caught birds has been redirected to other regions, notably the Middle East (Bush et al., 2014; Reino et al., 2017).

Saudi Arabia is going through a progressive transformation that stems from 2030 VISION emphasizing wildlife protection (vision2030.gov.sa). Several steps have been taken to enhance the protection and preservation of natural ecosystems and wildlife and to restore and rehabilitate impacted ones. Most recently, the release of the newly revised Environment's Law after and the creation of autonomous directorates within the Ministry of Environment would certainly improve environmental protection. Therefore, this research aims to shed light on the introduced avifauna in the Kingdom, routes of introduction, current spatial distribution, and potential impacts. Such knowledge is essential to prioritize research and management options targeting the halt of introductions and containment or eradication of established ones.

2. Methods

2.1. Study area

Saudi Arabia is mostly a hyper-arid desert, part of the subtropical desert, with very little rain. However, the south-western mountains are covered with trees and lack marked seasonality. The country is located between the Arabian Gulf to the east, and the red sea to the west, with an altitude that ranges between sea level to about 3000 m a.s.l. in the south-western mountains (Vincent, 2008). Thus, the Kingdom has variable geological foundation, as its covered by metamorphic rocks in the west, and sedimentary rocks to the east. This geomorphological variation is reflected on the existence of a diverse fauna and flora. The Saudi avifauna community is no different with more than 500 recorded species of these over 300 resident species, among which are 10 endemic species (Jennings, 2010).

2.2. Species occurrence

This research benefited from multiple sources of data including field work, citizen science and published literature. Bird surveys were conducted across the major cities of the Kingdom (Riyadh, Dammam, Jubail, Al-Qatif, Al-Hasa, Jeddah, Tabuk, Al Baha, Hafr Al-Batin, Al-Taif and Al-Qassim). Point counts were conducted in the first four hours of the day in the abovementioned cities, coordinates are provided in Bibby et al. (1992). Introduced species observed during the survey were recorded. Secondly, the authors' extensive field work across the Kingdom for the past 20 years provided supplementary data on birding hotspots as a potential introduction site and introduced species in the Kingdom. Thirdly, citizen science was a major source of information with detailed knowledge of exotic species recorded. The main source of citizen science is Bird Monitoring Group's (BMG) member observations. The BMG group has members in almost all provinces, regularly photographing birds in all seasons. Further information on year and route of introduction were obtained from information collected through the ABBA project (Jennings, 2010). In addition, citizen science records on Global Biodiversity Information Facility (GBIF) and similar data bases were reviewed for further assurance of fully covering any undocumented or uncommunicated observations. Finally, personal communications with wildlife photographers across the Kingdom were conducted by use of an online form.

3. Results

Twenty-one bird species belonging to eleven families were introduced and established in the Kingdom since the last century (Table 1). Several more species were previously recorded in the Kingdom, five in total, however, failed to establish sustaining populations (Table S1). Most of established species were accidently introduced at a single point, whereas a few have gradually expanded their range into the Kingdom from neighboring countries (Table 1). The highest numbers of introduced species belong to the

Columbidae family and the Pycnonotidae family, with three species each. The Fringillidae, Phisandae, Ploceidae, Psittacidae, and Sturnidae have two introduced species each whereas the Accipitridae family is represented by the Eastern subspecies of the Black-winged Kite as the only introduced bird of prey in the Kingdom.

Several routes of introductions were potentially responsible for the recorded introductions (Table 1). Pet trade was responsible for the highest number of introductions in the Kingdom, a total of 13 species (Fig. 2). The sources of traded birds were either native species from within the Kingdom or imported via international importers. Native to the south-western region, the Arabian Serin (*Crithagra rothschildi*), Rüppell's weaver (*Ploceus galbula*), and the Arabian Golden Sparrow (*Passer euchlorus*) were introduced into central and/or eastern regions. International pet trade introduced 10 species into the Kingdom, among those are Common Myna and Ring-necked Parakeet (Table 1 and S1, Fig. 1). Birds originating from within the Kingdom have localized and limited introduced ranges compared to their international counterparts (Table S2). The advancement of agricultural fields between 1970 and 1980 facilitated the range expansion of several species, doves and finches in particular (Table 1).

The distribution of introduced species varied across the Kingdom's provinces. The highest number of introduced species were recorded in Riyadh and Eastern provinces with 18 introduced species each (Fig. 1 and Table S2). Tabuk and Mecca have 10 and 9 introduced species, respectively (Fig. 1). Numbers of introduced species in the southern provinces were lower than the central and northern provinces. The lowest numbers of introduced species were recorded in Najran and Al Baha (Fig. 1; Table S2).

3.1. Notes on introduced species

3.1.1. Phasianidae

Two species of the Phasianidae family are recorded in the Kingdom, the Grey Francolin and the Common Quail (Figs. S1.1 and S1.2, respectively). The Common Quail is considered a passage migrant, with limited birds spending the winter in the Arabian Peninsula. The first documented breeding in the Kingdom was in

Table 1
List of introduced species and species exhibited range expansion recorded in Saudi Arabia including potential route of introduction and origin of the species.

Family	Common name	Scientific Name	Route	Origin	Reference
Introduced					
Phasianidae					
	Grey Francolin	*Francolinus pondicerianus*	Natural	International	Jennings, 2010
	Common Quail	*Coturnix coturnix*	Farming/Natural	International	Jennings, 2010
Columbidae					
	Eurasian Collared Dove	*Streptopelia decaocto*	Agriculture	International	Jennings, 2010
	Namaqua Dove	*Oena capensis*	Agriculture	International	Bundy and Warr 1980
Psittacidae					
	Ring-necked Parakeet	*Psittacula krameri*	Pet trade	International	Bundy and Warr 1980, Felemban 1993
	Alexandrine Parakeet	*Psittacula eupatria*	Pet trade	International	Jennings, 2010
Corvidae					
	House Crow	*Corvus splendens*	Shipping	International	Bundy and Warr 1980
Pycnonotidae					
	Red-vented Bulbul	*Pycnonotus cafer*	Pet trade	International	Jennings, 2010
	White-eared Bulbul	*Pycnonotus leucotis*	Pet trade	International	Jennings, 2010
	White spectacled Bulbul	*Pycnonotus xanthopygos*	Pet trade	National	Jennings, 2010
Sturnidae					
	Bank myna	*Acridotheres ginginianus*	Pet trade	International	Jennings, 2010
	Common myna	*Acridotheres tristis*	Pet trade	International	Bundy and Warr 1980, Felemban 1993
Passeridae					
	Arabian Golden Sparrow	*Passer euchlorus*	Pet trade	National	This study
Ploceidae					
	Streaked Weaver	*Ploceus manyar*	Pet trade	International	Jennings, 2010
	Ruppell's Weaver	*Ploceus galbula*	Pet trade	National	Alshamlih et al., 2020
Estrildidae					
	Red Avadavat	*Amandava amandava*	Pet trade	International	Jennings, 2010, This study in Al Hasa
	Indian Silverbill	*Euodice malabarica*	Pet trade	National	Jennings, 2010
Fringillidae					
	Arabian Serin	*Crithagra rothschildi*	Pet trade	National	Alshamlih et al., 2021
Range Expansion					
Accipitridae					
	Black-Winged Kite	*E. caeruleus vociferous*	Natural	National	This study
Columbidae					
	Laughing Dove	*Spilopelia senegalensis*	Agriculture	International	Jennings, 2010
Fringillidae					
	Desert Finch	*Rhodospiza obsolete*	Agriculture	International	Jennings, 2010

1981, expanding afterwards north and east. The establishment of a breeding population occurred after the establishment of several quail farms in the Kingdom; therefore, it is possible that farm escapees may have established the wild population. However, the possibility of migrants breeding and residing in the Kingdom cannot be ruled out. The Grey Francolin has been observed breeding in the wild in the Eastern Province, initially introduced into Bahrain and United Arab Emirates (Jennings, 2010). Two new populations of the Grey Francolin were discovered during our study, in the western and northern outskirts of Al-Qatif.

3.1.2. Accipitridae

The Black-winged Kite has an African subspecies, E. c. caeruleus, that is considered native to the south-west of the Kingdom, whereas recently the Asian subspecies was introduced into the Kingdom and experienced a rapid range expansion (Jennings, 2010). The earliest recorded expansion was in Hail and Eastern Province in 2012 (Fig. S1.3, Tables S1 and S2). Observations of breeding attempts were documented in the Eastern Province (personal communication, BMG).

3.1.3. Columbidae

The range expansion of doves is not restricted to Saudi Arabia, but is a rather global phenomenon (Fujisaki et al., 2010; Smith, 1987). For example, the Eurasian Collared Dove, originally native to India, has established one of the largest range expansions in the world, reaching North and Central America (Smith, 1987). In Saudi Arabia, three doves were introduced and have expanded widely, the first being the Eurasian Collared Dove present in almost all of the country (Fig. S1.4). Collared Doves are commensal with human inhabitation, existing in cities, parks, gardens and agriculture. In cities, Collared Doves feed on seeds and grains on the ground, and outside cities they may feed on invertebrates and young shoots. The second dove species is the Laughing Dove, (Fig. S1.5), which has spread across all of Saudi Arabia and expanded north to neighboring countries (Khoury et al., 2012). Finally, the Namaqua Dove, native to the Afrotropical region, was first recorded in the Arabian Peninsula in Yemen 1850. The first record in Saudi Arabia was in Jeddah in 1934 and remained restricted to regions south of the city until 1975, after which it expanded across most of the country (Table S2, Fig. S1.6). The observed expansion of doves in the Kingdom is correlated with the development of agricultural fields as well as dairy and poultry farms (Jennings, 2010).

3.1.4. Psittacidae

The Ring-necked Parakeet is one of the very first traded birds in the world (Newson et al., 2011). Invading 37 countries worldwide, it is considered one of the most successful invaders (Ancillotto et al., 2016). It is most likely that populations across Arabia, specifically Saudi Arabia, originated from independent introductions of escapees in each city (Fig. S1.8). Wild populations in the Kingdom are under hunting pressure for trading purposes; reducing the parakeet numbers and ultimately limiting their expansion (personal comm. pet traders). The other parakeet that has invaded the Kingdom is the Alexandrine Parakeet, (Figs. S1.7 and S1.8) that in its native range inhabits moist and dry forest land, cultivated areas, mangrove and plantations (Parr et al., 2010). In Saudi Arabia, suitable habitats of mangrove and cultivated areas exist primarily on the East and West coast. Both habitats have been invaded by the

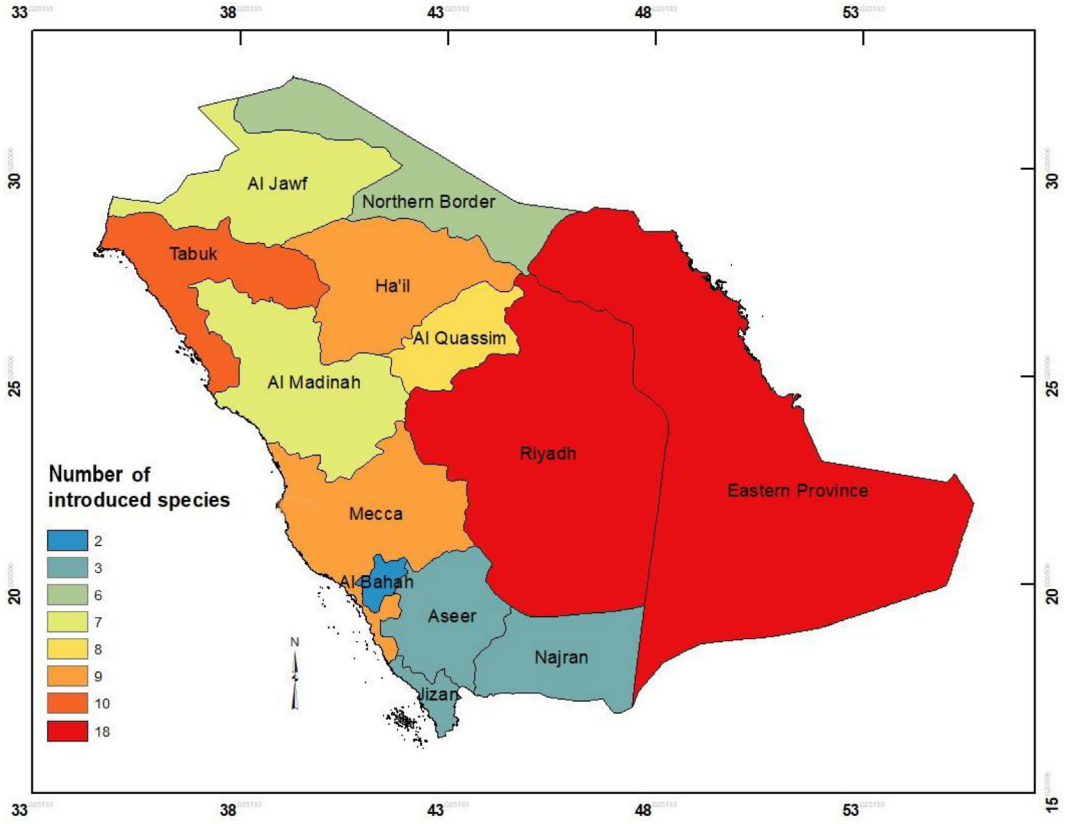

Fig. 1. Saudi Provinces, with number of introduced species recorded in each province.

Alexandrine Parakeet, however, in both localities no expansion was recorded.

3.1.5. Corvidae

The source of House Crow introduction in the Kingdom is believed to have occurred over several introductions (Jennings, 2010). House crow introduction and establishment were only successful in the coastal regions (Fig. S1.9). On the western coast, the first records of the House Crow were in Jeddah 1978, while the first records on the Eastern coast were in Dammam 1980 (Jennings, 2010). Given its restricted distribution to cities along the coastline, this species' establishment is seemingly dependent on humans.

3.1.6. Pycnonotidae

Historically the Pycnonotidae family, bulbuls, had only one species native to the Kingdom; the White-spectacled Bulbul in northern and western regions (Fig. S1.10). Although declining in its native range, the White-spectacled Bulbul has been introduced to the Eastern Province. An additional two members of the Pycnonotidae family have been established in the Kingdom; the White-eared Bulbul and the Red-vented Bulbul (Figs. S1.11 and S1.12). The first records of the White-eared Bulbul were in Eastern Province in the early 1900s (Jennings, 2010). Nowadays, it is distributed across the central and northern regions of the Kingdom. The Red-vented Bulbul, listed among the IUCN's 100 worst alien invasive species, was introduced in both the Eastern Province and Jeddah.

3.1.7. Sturnidae

The very first introduction of the Bank Myna in Saudi Arabia was in Dhahran, 1984. The second record was in Riyadh in 1989 but records there ceased after 2000 (Jennings, 2010). Currently, Bank Myna distribution is recorded only in Dhahran, Al-Qatif and Ras-Tanura (Fig. S1.13). It is possible that the cause of this limitation in Bank Myna numbers and distribution is because of the unparalleled success of the Common Myna (Fig. S1.14). The latter was first recorded successfully breeding in the Eastern Province in late 1970 (Bundy and Warr, 1980). In 1993, six pairs were recorded breeding at King AbdulAziz University in Jeddah (Felemban, 1993). Currently, the Common Myna is seen in almost all cities in the Kingdom after its latest spread in the southwest to Jizan (Jennings, 2010). Most numbers are seen in developed shore-

Fig. 2. Introduced species in Ras Tanura, Eastern Province. The Alexandrian Parakeet, Ring-necked. Parakeet and Common Myna seen on the same tree. © Atheer Ali.

lines, such as the eastern shorelines between Khobar to Jubail and west in Jeddah, as the myna benefits from human waste.

3.1.8. Passerridae

The Arabian Golden Sparrow, native to south and central mountains from Jeddah to Yemen, exhibited a natural range expansion up to Medina and Yanbu. Pet trade interest in the Arabian sparrow led to its introduction in two other cities; Riyadh 2013 and Qassim 2015. As of 2020 the Arabian Golden Sparrow was recorded, without confirmation of breeding, in Tarout Island and Al Hasa in the Eastern Province (Fig. 1.15)

3.1.9. Ploceidae

The weaver family has two species introduced in the Kingdom; Ruppell's Weaver and the Streaked Weaver (Figs. S1.16 and S1.17). Ruppell's Weaver is native to the southwest region, however, it has been introduced in the Eastern Province and Riyadh. The earliest record of this introduction was in Al-Qatif farms in 2011. Since then, Ruppell's Weavers have expanded their range reaching Al-Hasa and Ras Tanura in 2019 and have established a new population in Riyadh in the same year (Alshamlih et al., 2020). The earliest records of the Streaked Weaver were from 1989 in the Eastern Province and Riyadh. Successful establishment in southern Riyadh was confirmed by Jennings (2010). Currently, no records of breeding or establishment exist elsewhere. The breeding population of the Steaked Weaver in Riyadh was estimated at more than 150 pairs, all within Al-Hair in Autumn, 2020.

3.1.10. Estrildidae

Two members of the Estrildidae family are recorded as introduced in the Kingdom. The Red Avadavat is the earliest member of the family to be introduced, recorded in Riyadh in 1975 (Fig. S 1.18). The population in Riyadh is thought to have originated by escapees from an aviculture in the city and has been steadily growing in densely vegetated regions, helped by the lack of competing seed-eaters. The earliest expansion outside of Riyadh was in Dhahran 2003 and was recorded in Al-Qatif and Dammam in 2010. The Indian Silverbill (Fig. S1.19), native to the Eastern Province, has been introduced to the west coast; Jeddah, Tabuk and Hail. A population of Indian Silverbills exists in the city of Aqaba, Jordan, and is believed to have originated from the Saudi population (Khoury et al., 2012).

3.1.11. Fringillidae

Two members of the family were introduced in the Kingdom, the Desert Finch and Arabian Serin (Figs. S1.20 and 1.21 respectively). Endemic to the Arabian Peninsula and residing in the western region from the Yemeni border to Yanbu, the first record of the Arabian Serin beyond its native range was in Riyadh, 2012, mostly as cage escapees as it was documented in pet markets by Shobrak and Al Fagih (2012). In addition, the Arabian Serin has been regularly recorded in the Eastern Province with confirmed breeding attempts in 2019 and 2020 (Alshamlih et al., 2021). The introduction of Desert Finch is mostly driven as natural expansions from north to south. The source of Desert Finch in the Kingdom can be attributed to either Jordan or Iraq or both. Similar to its expansion in Jordan, introduction in the Kingdom is correlated with agricultural fields (Jennings, 2010). In Saudi Arabia, Desert Finch expansion has reached Al-Kharj in the center, and Medina in the west.

4. Discussion

Despite the extreme aridity, the Kingdom of Saudi Arabia has 26 introduced species, 21 of which established a sustaining population in the wild. Many of the introduced species are cage birds, potentially introduced as cage escapees. Among the recorded species are the Indian House Crow and Common Myna, Red-vented Bulbul which are globally known invasive species of their drastic impacts. The Common Myna and Red-vented Bulbul are considered one of the 100 worst alien invasive species in the world (Lowe et al., 2000). Three of the introduced species, the Arabian Serin, Arabian Golden Sparrow and Ruppell's Weaver, comprise the first recorded introductions globally. Like most other introductions, these species were introduced by pet trade, however, their origin was from within the Kingdom.

The introduction of novel species in new habitats may cause drastic ecological, economic and social impacts. Ecologically, invasive species compete with native species for habitat and resources, leading to potential declines in native populations. Introduced species have been reported to impact agricultural fields and infrastructure and transmit disease (Pyšek and Richardson, 2010; Vilà and Hulme, 2017). Despite the long history of introductions in the Kingdom, very limited scientific research or management actions have been directed at introduced species. Therefore, the following sections aim at reviewing published and observed impacts of reported species in this study. Such information is of high importance for future scientific research as well as management actions.

4.1. Potential impact

Competition of invasive species with their native counterparts for resources is widely documented. It has been documented that invasive species exhibiting a flexibility in their feeding have higher impacts and chances of successful invasion (Webb et al., 2014). Among the reported introduced species in the Kingdom is the common myna, which is listed as one of the 100 worst alien invasive species globally (Lowe et al., 2000). Mynas are known for their feeding flexibility, thereby increasing their access to food resources and ultimately their impact on native fauna (Federspiel et al., 2017). Food competition between invasive mynas and bulbuls is threatening the survival of the endemic Olivaceous Bulbul *Hypsipetes borbonicus olivaceus* in Mauritius. The omnivorous House Crow has been reported to feed on live animals, fruits and human waste; showing a high association with human settlements (Wilson et al., 2015; Yosef et al., 2019). Furthermore, the House Crow has been observed carrying out kleptoparasitic attacks on other native species (Yosef et al., 2012). In Europe, the Ring-necked Parakeet exploits anthropogenic food sources, such as bird feeders (Clergeau and Vergnes, 2011). Furthermore, the feeding behavior of the Ring-necked Parakeet is coupled with aggressive behavior towards native species (Le Louarn et al., 2016; Shiels et al., 2018). This superior feeding flexibility and the associated increase in accessibility to food makes Ringnecked Parakeets the most abundant species at feeding sites, displacing smaller native birds (Le Louarn et al., 2016). In west Mexico, the introduction of the Eurasian Collared Dove led to a decline in food as well as breeding resources of native dove and pigeon species (Camacho-Cervantes and Schondube, 2018).

Invasive species are the perpetrator of the decline of not only bird species but other taxa (Martin-Albarracin et al., 2015). Impact of invasive species increases with social gregarious birds. For instance, the gregarious behavior of mynas while feeding, roosting, and breeding has intensified their ecological impacts (Grarock et al., 2012). On Mauritius, mynas have been observed predating on the endangered endemic skink (Bissessur and Florens, 2018). On Bermuda, the introduced Kiskadee Flycatcher, *Pitangus sulphuratus*, is thought to be responsible for the eradication of the endemic cicada, *Tibicen bermudiana* (Sterrer et al., 2004).

Impact of introduced species on their native counterparts may include aggression when competing for resources other than food.

Failed breeding and consequent reduced numbers of native species has been linked to aggressive behavior exhibited by invasive species during the breeding season (Hernández-Brito et al., 2014). For instance, the impact of Common Mynas increases during the breeding season, particularly against passerines (Lever, 2005). Particularly, cavity nesters are the most impacted species by the Common Myna because of the shared nesting preference (Grarock et al., 2012). Red-vented Bulbuls exhibit aggressive behavior towards native species, leading to nest failure and death of fledged young (Blanvillain et al., 2003). In addition, other cavity nesters, such as Ring-necked Parakeets replace native cavity breeders (Strubbe and Matthysen, 2009). In Saudi Arabia, it is reported that the arrival of a colony of parakeets in Wadi Hanifa successfully replaced Rock Doves from their nesting cavities (Jennings, 2010). In addition, invasive species preying on chicks and eggs as well as adults have caused the decline of native species. Jennings associated the decline of Black Kite (*Milvus migrans*) breeding population in Jeddah and Aden to House Crow nest predation (Jennings, 2010). Therefore, the possible impact of the reported introduced species in the Kingdom is potentially high.

Invasive species are known for having devastating impacts on most economic sectors. Globally, major focus has been directed at studying biological invasions impacts, however, in the Kingdom, only a single study was conducted to assess the impact of White-eared Bulbul on date farms in the Eastern Province (El-Shafie, 2018). White-eared Bulbul feeding on date palm caused a 20% loss of palm productivity. Other studies further report on mitigation measures carried out by farmers, such as fruit bagging, to prevent fruit loss and injury because of invasive species (Harhash et al., 2020). However, these loss-control measures are an added cost, reducing farms' profitability. Globally, invasive species are linked to decreased agricultural profitability, many of which are associated with bulbuls and weavers. Weavers, in their native range, are considered one of the major farm pests, causing 50% production decline (Bruggers, 1980; Maurice et al., 2017). Likewise, it is expected that the Streaked Weaver and Ruppell's Weavers, both known of being gregarious in their native range, will have drastic impacts on agricultural fields in the Kingdom. It has already been documented in Al-Qatif that Rüppell's weavers exhibit flexible feeding behavior, feeding on available seasonal crops such as dates, figs, blackberries and grains (Alshamlih et al., 2020). Other introduced species, e.g. Red-vented and Redwhiskered Bulbuls, are reported to destroy fruits, flowers, beans, tomatoes, peas and ripe fruit (El-Shafie, 2018; Thibault et al., 2018). Similarly, Common Mynas and House Crows are known of their high impact on agricultural activities because of their omnivorous feeding on crops and invertebrates (Fraser et al., 2015; Wilson et al., 2015). However, the effect of crows is not limited to agriculture; free range poultry sustains a high cost because of House Crow predation of free birds (Bestman and Bikker-Ouwejan, 2020). Thus, assessing the impacts of the reported species is of high importance to mitigate their effect and prioritize wildlife management actions.

The social impact of introduced birds in Saudi is expected to be high, despite the lack of evidence. Myna droppings are a public health issue, as they carry infectious bacteria and parasites (Pyšek and Richardson, 2010; Vilà and Hulme, 2017). In Australia, mynas are implicated in the spread of malaria as they have been found carrying two strains of plasmodium (Clark et al., 2015). Other social impacts of invasive species extend to causing wounds and bites affecting human well-being. In public places, parks, and sometimes residences, mynas and crows are known to fearlessly steal human food (Pyšek and Richardson, 2010; Vilà and Hulme, 2017). Moreover, crows and mynas are public nuisances as they are vocal throughout the year; such impact is intensified in public and touristic areas. In Al-Qatif, during breeding season, House Crows are reported aggressively attacking humans in defense of their nests. Based on our observations, in agricultural cities, human-crow interactions increase as crows were seen in farms and landscaping trees, thus exerting more aggressive behavior during breeding season.

4.2. Impact of pet trade harvest on native birds

Hunting wild populations for the purpose of supplying pet markets is a major threat to species' survival globally. For example, many Brazilian birds are threatened mainly because of hunting for trading in pet markets around the world (Alves et al., 2013). The latest three introductions in the Kingdom are native birds that reside in the mountainous southwest region. Three species, the Arabian Serin, Arabian Golden Sparrow and Ruppell's Weaver, were introduced into Riyadh in the center and the Eastern Province. The origin of these introductions can only be attributed to pet trade. Native birds have been previously observed in pet markets in different cities of the Kingdom, among which are wild-caught and endangered species (Shobrak and Al Fagih, 2012; Aloufi and Eid, 2014). In fact, the Arabian Serin was reported in Dammam city, with colour-rings fitted on their legs (Alshamlih et al., 2021). These introductions highlight the alarming impact that hunting for trading purposes has on wild birds, especially endemics in the Kingdom. Therefore, although pet trade is correlated with bird introductions across the Kingdom, its impact is potentially threatening native species in their native habitat. Thus, to protect wild and endemic birds, pet markets need to be closely monitored to prevent sale of native birds and ultimately the capture of wild birds.

5. Conclusion

Here, we present a list of introduced species along with most probable source of introduction and a narrative on their expansion processes. Data presented, i.e: routes of introduction and causes of establishment and spread are the basis for management and eradication of invasive species (Early et al., 2016). Clearly, the main source of introductions in the Kingdom is pet trade, which is a global issue impacting native communities. Therefore, countries around the world are introducing regulations banning trade of wild-caught birds, e.g. Europe (Reino et al., 2017). Many of the reported introduced species in the Kingdom have triggered environmental issues in other countries. Although their impacts in the Kingdom have not been studied yet, active monitoring of the Kingdom's introduced species provides scientific knowledge important to wildlife management. With such knowledge at the disposal of wildlife authorities, prioritization of wildlife management actions would be facilitated.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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References

Aloufi, Abdulhadi, Eid, Ehab, 2014. Conservation perspectives of illegal animal trade at markets in Tabuk, Saudi Arabia. Traffic Bulletin 26 (2), 77–80.
Alshamlih, M., Alzayer, M., Hajwal, F., 2020. Rüppell's weaver, Ploceus galbula Rüppell, 1880 invasion of the Eastern Arabian Peninsula: potential economic and social impacts. BioInvasions Rec. 9, 158–164. https://doi.org/10.3391/bir.2020.9.1.20.
Alshamlih, M., Alzayer, M., Reino, L., Hajwal, F., 2021. Pet trade and the introduction of endemic species: the case of the Arabian Serin Crithagra rothschildi Ogilvie-Grant, 1902. BioInvasions Rec. 10 (2), 499–505. https://doi.org/10.3391/bir.2021.10.2.27.
Alves, R.R.N., Lima, J.R.D.F., Araujo, H.F.P., 2013. The live bird trade in Brazil and its conservation implications: an overview. Bird Conservation International 23 (1), 53–65. https://doi.org/10.1017/S095927091200010X.
Ancillotto, L., Strubbe, D., Menchetti, M., Mori, E., 2016. An overlooked invader? Ecological niche, invasion success and range dynamics of the Alexandrine parakeet in the invaded range. Biol. Invasions 18 (2), 583–595.
Bestman, M., Bikker-Ouwejan, J., 2020. Predation in organic and free-range egg production. Animals 10 (2), 177. https://doi.org/10.3390/ani10020177.
Bibby, C.J., Burgess, N.D., Hill, D.A., 1992. Bird census Techniques. Academic Press, Boston.
Bissessur, P., Florens, F., 2018. Predation of the Mauritius endemic Macchabé Skink, Gongylomorphus bojerii fontenayi, by the Common myna, Acridotheres tristis. Bull. Phaethon 48, 91–93.
Blackburn, T.M., Bellard, C., Ricciardi, A., 2019. Alien versus native species as drivers of recent extinctions. Front. Ecol. Environ. 17 (4), 203–207.
Blackburn, T.M., Dyer, E., Su, S., Cassey, P., 2015. Long after the event, or four things we (should) know about bird invasions. J. Ornithol. 156 (S1), 15–25.
Blanvillain, C., Salducci, J.M., Tutururai, G., Maeura, M., 2003. Impact of introduced birds on the recovery of the Tahiti Flycatcher (Pomarea nigra), a critically endangered forest bird of Tahiti. Biol. Conserv. 109 (2), 197–205.
Brochet, A.-L., Jbour, S., Sheldon, D.R., Porter, R., Jones, V.R., Al Fazari, W., Al Saghier, O., Alkhuzai, S., Al-Obeidi, L.A., Angwin, R., 2019. A preliminary assessment of the scope and scale of illegal killing and taking of wild birds in the Arabian peninsula, Iran and Iraq. Sandgrouse 41, 155–175.
Bruggers, R.L., 1980. The Situation of Grain-Eating Birds in Somalia, in: E.P., C. (Ed.), The Ninth Vertebrate Pest Conference. University of California, Davis, California 95616, California, U.S.A.
Bundy, G., Warr, E., 1980. A check-list of the Arabian Gulf states. SAndgrouse 1, 4–49.
Bush, E.R., BAKER, S.E., Macdonald, D.W., 2014. Global trade in exotic pets 2006–2012. Conserv. Biol. 28 (3), 663–676.
Camacho-Cervantes, M., Schondube, J.E., 2018. Habitat use by the invasive exotic eurasian collared-dove (streptopelia decaocto) and native dove species in the chamela-cuixmala region of west mexico: a journal of ornithology. Wilson J. Ornithol. 130, 902–907.
Carpio, A.J., Álvarez, Y., Oteros, J., León, F., Tortosa, F.S., 2020. Intentional introduction pathways of alien birds and mammals in Latin America. Global Ecol. Conserv. 22, e00949. https://doi.org/10.1016/j.gecco.2020.e00949.
Clark, N.J., Olsson-Pons, S., Ishtiaq, F., Clegg, S.M., 2015. Specialist enemies, generalist weapons and the potential spread of exotic pathogens: malaria parasites in a highly invasive bird. Int. J. Parasitol. 45 (14), 891–899.
Clavero, M., Brotons, L., Pons, P., Sol, D., 2009. Prominent role of invasive species in avian biodiversity loss. Biol. Conserv. 142 (10), 2043–2049.
Clergeau, P., Vergnes, A., 2011. Bird feeders may sustain feral Rose-ringed parakeets (Psittacula krameri) in temperate Europe. Wildlife Biol. 17 (3), 248–252.
Courchamp, F., Fournier, A., Bellard, Céline, Bertelsmeier, C., Bonnaud, E., Jeschke, J. M., Russell, J.C., 2017. Invasion biology: specific problems and possible solutions. Trends Ecol. Evol. 32 (1), 13–22.
Davis, M.A., Thompson, K., Grime, J.P., 2001. Charles S. Elton and the dissociation of invasion ecology from the rest of ecology. Divers. Distrib. 7, 97–102.
Didham, R.K., Tylianakis, J.M., Hutchison, M.A., Ewers, R.M., Gemmell, N.J., 2005. Are invasive species the drivers of ecological change? Trends Ecol. Evol. 20 (9), 470–474.
Early, R., Bradley, B.A., Dukes, J.S., Lawler, J.J., Olden, J.D., Blumenthal, D.M., Gonzalez, P., Grosholz, E.D., Ibañez, I., Miller, L.P., Sorte, C.J.B., Tatem, A.J., 2016. Global threats from invasive alien species in the twenty-first century and national response capacities. Nat. Commun. 7, 12485.
El-Shafie, H.A., 2018. The frugivorous white-eared bulbul bird, Pycnonotus leucotis depredating date fruits: biology, feeding ecology and management. Outlooks Pest Manag. 29 (4), 153–157.
Federspiel, I.G., Garland, A., Guez, D., Bugnyar, T., Healy, S.D., Güntürkün, O., Griffin, A.S., 2017. Adjusting foraging strategies: a comparison of rural and urban common mynas (Acridotheres tristis). Anim. Cognit. 20 (1), 65–74.
Felemban, H.M., 1993. On exotic birds imported into Jeddah, Saudi Arabia. Zool. Middle East 8 (1), 15–16.
Fraser, D., Aguilar, G., Nagle, W., Galbraith, M., Ryall, C., 2015. The house crow (Corvus splendens): a threat to New Zealand? ISPRS Int. J. Geo-Inf. 4 (2), 725–740.
Fujisaki, I., Pearlstine, E.V., Mazzaroti, F.J., 2010. The rapid spread of invasive Eurasian Collared Doves Streptopelia decaocto in the continental USA follows human-altered habitats. Ibis 152, 622–632.
Grarock, K., Tidemann, C.R., Wood, J., Lindenmayer, D.B., Sueur, C., 2012. Is it benign or is it a Pariah? Empirical evidence for the impact of the common Myna (Acridotheres tristis) on Australian birds. PloS one 7 (7), 1.
Harhash, M., Mosa, W., El-Nawam, S.M., Gattas, H.R., 2020. Effect of bunch covering on yield and fruit quality of" Barhee" date palm cultivar. Middle East J. 9, 46–51.
Hernández-Brito, D., Carrete, M., Popa-Lisseanu, A.G., Ibáñez, C., Tella, José.L., Chiaradia, A., 2014. Crowding in the city: losing and winning competitors of an invasive bird. PLoS One 9 (6). e100593.
Jennings, M.C., 2010. Atlas of the Breeding Birds of Arabia. King Abdulaziz City for Science and Technology.
Khoury, F., Amr, Z., Hamidan, N., Al Hassani, I., Mir, S., Eid, E., Bolad, N., 2012. Some introduced vertebrate species to the Hashemite Kingdom of Jordan. Vertebr. Zool. 62, 435–451.
Le Louarn, M., Couillens, B., Deschamps-Cottin, M., Clergeau, P., 2016. Interference competition between an invasive parakeet and native bird species at feeding sites. J. Ethol. 34 (3), 291–298.
Lever, C., 2005. Naturalised Birds of the World. T and A D Poyser London, UK.
Lowe, S., Browne, M., Boudjelas, S., De Poorter, M., 2000. 100 of the World's Worst Invasive Alien Species: A Selection from the Global Invasive Species Database. Invasive Species Specialist Group Auckland..
Magory Cohen, T., McKinney, M., Kark, S., Dor, R., 2019. Global invasion in progress: modeling the past, current and potential global distribution of the common myna. Biol. Invasions 21 (4), 1295–1309.
Martin-Albarracin, V.L., Amico, G.C., Simberloff, D., Nuñez, M.A., Roiloa, S.R., 2015. Impact of non-native birds on native ecosystems: a global analysis. PLoS One 10 (11). e0143070.
Maurice, M.E., Fuashi, N.A., Agiamte-Mbom, V.B., Lengha, T.K., 2017. The Farmers' perception on weaverbird pest on agricultural crop damage in Ekona Farming Area, Southwest Region, Cameroon. J. Biodivers. Manag. For. 6, 5.
McGeoch, M.A., Genovesi, P., Bellingham, P.J., Costello, M.J., McGrannachan, C., Sheppard, A., 2016. Prioritizing species, pathways, and sites to achieve conservation targets for biological invasion. Biol. Invasions 18 (2), 299–314.
Newson, S.E., Johnston, A., Parrott, D., Leech, D.I., 2011. Evaluating the population-level impact of an invasive species, Ring-necked Parakeet Psittacula krameri, on native avifauna. Ibis 153, 509–516.
Parr, M., Juniper, T., D'Silva, C., Powell, D., Johnston, D., Franklin, K., Restall, R., 2010. Parrots: A Guide to Parrots of the World. Bloomsbury Publishing.
Pejchar, L., Mooney, H.A., 2009. Invasive species, ecosystem services and human well-being. Trends Ecol. Evol. 24 (9), 497–504.
Pimentel, D., Zuniga, R., Morrison, D., 2005. Update on the environmental and economic costs associated with alien-invasive species in the United States. Ecol. Econ. 52 (3), 273–288.
Pyšek, P., Hulme, P.E., Simberloff, D., Bacher, S., Blackburn, T.M., Carlton, J.T., Dawson, W., Essl, F., Foxcroft, L.C., Genovesi, P., Jeschke, J.M., Kühn, I., Liebhold, A.M., Mandrak, N.E., Meyerson, L.A., Pauchard, A., Pergl, J., Roy, H. E., Seebens, H., Kleunen, M., Vilà, M., Wingfield, M.J., Richardson, D.M., 2020. Scientists' warning on invasive alien species. Biol. Rev. 95 (6), 1511–1534.
Pyšek, P., Richardson, D.M., 2010. Invasive species, environmental change and management, and health. Annu. Rev. Environ. Resour. 35 (1), 25–55.
Reino, L., Figueira, R., Beja, P., Araújo, M.B., Capinha, César, Strubbe, D., 2017. Networks of global bird invasion altered by regional trade ban. Sci. Adv. 3 (11). https://doi.org/10.1126/sciadv.1700783.
Shiels, A.B., Bukoski, W.P., Siers, S.R., 2018. Diets of Kauai's invasive rose-ringed parakeet (Psittacula krameri): evidence of seed predation and dispersal in a human-altered landscape. Biol. Invasions 20 (6), 1449–1457.
Shobrak, M., Al Fagih, A.S., 2012. Wildlife Trade in Taif Region. Phoenix 28, 2.
Simberloff, D., Martin, J.-L., Genovesi, P., Maris, V., Wardle, D.A., Aronson, J., Courchamp, F., Galil, B., García-Berthou, E., Pascal, M., Pyšek, P., Sousa, R., Tabacchi, E., Vilà, M., 2013. Impacts of biological invasions: what's what and the way forward. Trends Ecol. Evol. 28 (1), 58–66.
Smith, P.W., 1987. The Eurasian collared-dove arrives in the Americas. Am. Birds 41, 1370–1379.
Sterrer, W., Glasspool, A., De Silva, H., Furbert, J., 2004. Bermuda—an island biodiversity transported. In: The Effects of Human Transport on Ecosystems: Cars and Planes, Boats and Trains. Royal Irish Academy, Dublin, pp. 118–170.
Strubbe, D., Matthysen, E., 2009. Experimental evidence for nest-site competition between invasive ring-necked parakeets (Psittacula krameri) and native nuthatches (Sitta europaea). Biol. Conserv. 142 (8), 1588–1594.

Thibault, M., Vidal, E., Potter, M.A., Sanchez, T., Brescia, F., Derraik, J.G.B., 2018. The invasive red-vented bulbul (pycnonotus cafer) outcompetes native birds in a tropical biodiversity hotspot. PLoS One 13 (2). e0192249.

Vilà, M., Hulme, P.E., 2017. Ecosystem Services, and Human Well-Being. In: Vilà, M., Hulme, P.E. (Eds.), Impact of Biological Invasions on Ecosystem Services. Springer International Publishing, Cham, pp. 1–14. https://doi.org/10.1007/978-3-319-45121-3_1.

Vincent, P., 2008. Saudi Arabia: An Environmental Overview. CRC Print, London.

Webb, J.K., Letnic, M., Jessop, T.S., Dempster, T., 2014. Behavioural flexibility allows an invasive vertebrate to survive in a semi-arid environment. Biol. Lett. 10 (2), 20131014. https://doi.org/10.1098/rsbl.2013.1014.

Wilson, R.F., Sarim, D., Rahman, S., 2015. Factors influencing the distribution of the invasive house crow (Corvus splendens) in rural and urban landscapes. Urban Ecosyst. 18 (4), 1389–1400.

Yosef, R., Zduniak, P., Poliakov, Y., Fingerman, A., 2019. Behavioural and reproductive flexibility of an invasive bird in an arid zone: a case of the Indian House Crow (Corvus splendens). J. Arid Environ. 168, 56–58.

Yosef, R., Zvuloni, A., Yosef-Sukenik, N., 2012. House Crow (Corvus splendens) attempt to cooperatively kleptoparasitize western Osprey (Pandion haliaetus). Wilson J. Ornithol. 124 (2), 406–408.