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RESEARCH ARTICLE
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Phenotypical Characterization of the Indian Crow (*Corvus splendens*) as an Invasive Bird in the Sultanate of Oman

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ABSTRACT

Invasive species can have immense consequences on ecosystems, and their impact is more extensive than that of any native species. They can modify diverse characteristics in habitats, such as topography, nutrient availability, water management, and energy transfer, and these alterations persist long-term despite efforts to reverse them. This study aimed to capture the morphological features of this bird in various areas and investigate the differences in phenotypes between males and females. Samples of the Indian Crow were collected from some selected governorates of Oman. The birds were captured using non-lethal techniques and were euthanized at the point of capture. The morphological characterization of the birds was conducted. Quantitative measurements were performed, and anatomical sexing was carried out to differentiate between males and females. The morphological characterization revealed that the color of primary, secondary, and tail feathers, as well as the alula, beak, back, and eye ring, was predominantly black (100%), with only one exception in the eye ring (99.7% black, 0.3% blue). Significant differences were found across all measured traits. Males had significantly higher mean body weight, body width, body circumference, wing length, tarsus length, wingspan, beak length, and body length than females ($P<0.001$). Significant differences were found for several traits among the governorates. There were no significant associations between gender and any of the phenotypic characteristics. The Indian Crow flight feather was highly chromatically integrated, with primary, secondary, tail, and alula feathers mainly black and minor blue coloration, indicating strong genetic regulation of feather coloration. The morphometric analysis revealed that males are significantly larger than females, indicating high sexual size dimorphism.

Keywords: Invasive birds, Indian Crow, Phenotypic traits, Sultanate of Oman

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INTRODUCTION

Invasive species may have monumental consequences on ecosystems, and their impact is more extensive than that of any native species (Grzędzicka & Reif, 2020). Interference is one of the primary means by which these

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invasive species affect native ecosystems (Strubbe et al., 2011). These invader species have the capacity to compete favorably because they possess a higher net reproductive rate, a rapid growth rate, and a superior ability to withstand diverse adverse environmental conditions (Evans et al., 2021). This can result in either a reduction in the population level or the disappearance of native species from their habitats (Arya et al., 2021; Nadhairi et al., 2024). In general, invasive species are a global phenomenon that poses a major threat to the environmental, economic, and health structures (Charles & Dukes, 2007; Dong et al., 2021). The invasive bird species can modify various habitat characteristics, including topography, nutrient availability, water management, and energy transfer. These alterations are long-term despite efforts to reverse them (Grarock et al., 2012; Anjum et al., 2021).

Another major effect is predation by invasive species on local inhabitant species, which has been observed in areas where these species are present. Such predators can cause significant harm to native prey, especially if the invaders are on an island, where aboriginal animals are unaccustomed to facing new predators (Brochier et al., 2010; Ngongolo et al., 2025). According to the International Union for Conservation of Nature (IUCN), invasive species are those living creatures that successfully establish themselves in a new environment and then spread rapidly, potentially out-competing the native species for resources, consuming them, or otherwise harming the native species and their habitats, thereby causing a loss of biological diversity (Smith, 2020; Kumar, 2023). These invasive species could be plants, animals, fungi, or microorganisms. Their arrival in a particular ecological zone is usually due to human intervention, such as trade, transport, and/or ecosystem alteration, which provides room for migration.

The effects of invasive species are numerous and impact various aspects of the lives of both human and animal populations in their immediate environment (Heringer et al., 2024). Invasive species imperil the survival of native species owing to factors including competition for sustenance, predation, and disease transmission (Freed & Cann, 2009; Johana et al., 2022). This can have profound impacts on the organization and processes of ecosystems at varying levels (Yong et al., 2024). However, invasive species possess certain qualities; for example, they proliferate rapidly, swiftly adapt to novel environments, and aggressively compete with other species within the immediate environment (Ricciardi & Ryan, 2018). In terms of potential health risks, invasive species can either bring in new diseases or worsen the transmission of existing ones (Moyes et al., 2017).

The Global Invasive Species Database (GISD) by IUCN offers information regarding invasive species, including their distribution, effects, and control applied globally (Blackburn et al., 2014). The GISD claimed that invasive species are among the primary agents with adverse impacts on global diversity, second only to habitat loss. In the Arabian Peninsula, it was reported that the Indian Crow has out-competed numerous native birds, thereby adversely impacting the conservation of particular avian species (Liu et al., 2021). It was also reported that invasive species have caused social and economic damage, according to the IUCN report. In Asia alone, the economic damages accounted for more than $100 billion in losses to the economies every year (Liu et al., 2021; Kamalakannan, 2023). This implies that the costs involved have implications for agriculture, forestry, fisheries, and other industries, primarily in terms of species-state management and control of invasive species (Paini et al., 2016). The Indian house crow is a medium-sized crow with an approximate length of 42-44cm. It has a unique appearance, featuring black body plumage and a smoky-grey collar on the neck and breast (Nadhairi et al., 2024; Khan et al., 2025). The appearance of the beak, legs, and feet is black. Males are usually slightly bigger than females, and both sexes are phenotypically similar (Fraser et al., 2015).

The Indian house crow can easily adapt to a new environment and is mostly seen in urban areas. They mostly scavenge for food remnants (Khvatov et al., 2021). They are usually intelligent and have the ability to easily solve their problem (Shimba & Jonah, 2017). Indian crows are usually vocal, producing a wide range of calls that include harsh caws and other sounds (Yosef et al., 2019). In their habitat, they are considered social birds, mostly move in groups (Itahara & Kano, 2024), and they appear to be aggressive, particularly when issue concern their territory or nests (Behrouzi-Rad, 2010; Saleh et al., 2022). They are considered omnivorous, mainly eating garbage, food remnants, vegetables, and insects, which makes them highly opportunistic feeders (Suliman et al., 2010; Jaipal & Singh, 2023).

This study focuses on the phenotypical characterization of the Indian Crow as an invasive bird species in the Sultanate of Oman. The aim is to conduct a morphological analysis of this bird in various regions of Oman, investigating the differences in phenotypes between males and females, and looking into variations based on geographical location; hence making it easier to embark on a genotypic study and formulation of managerial strategies to control this invasive bird in the future.

MATERIALS & METHODS

Samples Collections

The sample population was collected from four selected governorates of Oman out of the existing 10 governorates. This was achieved during one of the eradication campaigns involving invasive birds in Muscat, Dhofar, North Al Batinah, and South Al Sharqiyah. A total of approximately 367 adult male and female Indian crows were obtained. The sample size determination followed the resource equation method as described by Pakgohar and Mehrannia (2024).

The birds included in this study were obtained through the national invasive bird control program, which involved the culling of Indian crows using air rifles as part of population management efforts. The control team, comprising trained wildlife personnel, carried out the culling under approved protocols. The culled birds were immediately collected and transported to A'Sharqiyah University laboratories for further analysis.

The wildlife personnel recruited for this research were trained to accurately identify the target bird species, which is the Indian crow. The identification process required proper training on several aspects of species identification, including the size of the bird, plumage color, and other unique markings. Graphical illustrations were used, and practical outdoor activities provided trainees with the opportunity to develop and enhance their identification skills, as described by Morris and Parsons (2023). Key capturing and retention practices covered in the training included ethical capture methods. Measures were taken to prevent the use of lethal force while subduing birds and to ensure the equipoise and skins of those captured remained intact. The birds were captured using mist nets and baited traps under the supervision of a wildlife veterinarian. The carcasses of the birds were then transported forthwith to the laboratory and stored in the special airtight thermos-chambers for further processing as described by Morris and Parsons (2023).

Study Area and Sample Size

The study was conducted across four governorates in the Sultanate of Oman, selected to represent diverse ecological and climatic zones: Muscat, Dhofar, North Al Batinah, and South Al Sharqiyah. These regions differ markedly in topography, urbanization, and climate, allowing for a robust assessment of regional morphological variation in Indian crow populations.

The majority of the regions in the Sultanate of Oman have a non-tropical, non-wet climate, with summer monsoons and hot, hazy conditions in most of the country. The average yearly temperature ranges from 10 to 12°C in the north, while it ranges from 16 to 18°C in the South. The annual average rainfall is extremely low, ranging from 150 to 300mm in the northern region, whilst the range in the South is from 50 to 150mm, excepting the Dhofar, in contrast, is situated in the far South of the country and has a monsoon-influenced climate (Mushtaque & Choudri, 2012), with unique seasonal vegetation during the Khareef season. The Dhofar governorate includes urban centers like Salalah, as well as agricultural lands, coastal zones, and green hills, offering a contrasting habitat to northern Oman (Al-Sarmi et al., 2017).

Muscat governorate is one of the study areas. It is the capital city of Oman, and the climatic conditions are predominantly hot and typically arid (Gunawardhana & Al Rawas, 2014). The summer season is long, mainly from May to October, and it is extremely hot. The average daily temperature in summer reaches as high as 49℃ (Zurigat et al., 2021). The winter season is relatively warm, but it can occasionally be cold. The average annual rainfall is estimated to be 100mm, with precipitation occurring during November to April (Gunawardhana & Al Rawas, 2014). A significant percentage of the country's human population (40%) resides within Muscat, which attracts many wild migratory avian species due to the availability of waste food and water (Mushtaque & Choudri, 2012).

North Al Batinah lies in the northwestern coastal strip, featuring fertile agricultural plains and a mix of urban and semi-urban environments. The region benefits from its proximity to the Hajar Mountains and the Sea of Oman, which supports year-round crop production and may influence bird diet and morphology (Al-Tubi et al., 2024). Due to the coastal border with the Gulf of Oman and fertile agricultural land, there are considerable migratory avian species spread across the Al Batinah region, as reported by Al-Rawas et al. (2024).

The South Sharqiyah is located in eastern Oman, bordered by the Arabian Sea and inland desert areas. The region includes a mixture of small towns, fishing villages, and open desert habitats. Its drier, hotter climate and sparse vegetation offer a distinctly different setting from Dhofar or Muscat. (Al-Tubi et al., 2024). The region has very low annual rainfall with approximately 100mm. According to Koppen and Geiger, the estimated yearly temperature is 27℃ (Al-Awadhi & Mansour, 2015). There was a reported presence of various migratory avian species in the region due to the coastal boundary (Nahairi et al., 2024) (Fig. 1).

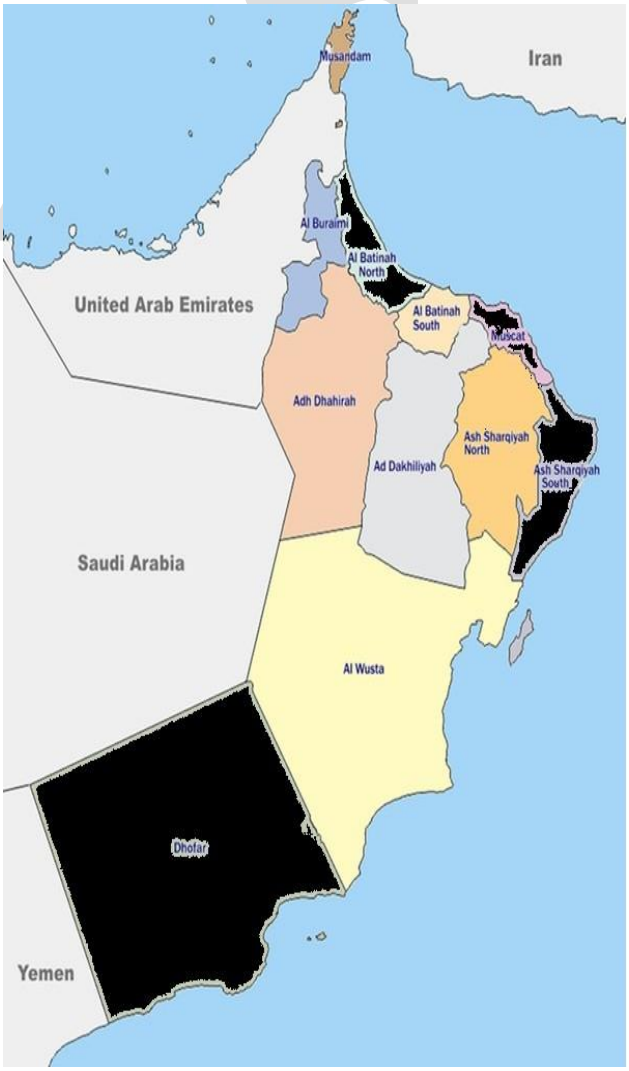

Fig. 1: Map of the Sultanate of Oman, indicating where the Indian Crow were sampled; four governorates were randomly selected out of ten for sampling. Sampling regions were colored in black.

A total of 367 Indian crow samples were collected across the study area. These sample sizes provide valuable insight into the regional presence and abundance of the

species. The spatial distribution of the Indian crows in these governorates may be influenced by factors such as habitat availability, human activity, and food resources. By examining their occurrence across different regions, this study aims to contribute to a better understanding of the species' population dynamics and potential ecological impact in Oman.

Morphological Characterization of the Indian Crow

The physical and general examination of the Indian Crow (*Corvus splendens*) was conducted in the laboratory, utilizing qualitative and quantitative anatomical features of the bird. These assessments included anthropometric measurements of various bodily parts and features, as well as color gradients over specific bodily components, as described by Ali (2021).

Measured Quantitative Data

Weight: All the birds were weighed on a sensitive digital balance (FA1204N, Digital Laboratory Balance Scale, Changhour, China) capable of measuring the weight to the nearest gram.

Body width: A digital caliper was used for this measurement; it was recorded by placing the end of the caliper's opening on the broadest point of the body, thereby measuring the size and stature of the body.

Body circumference: Taking a circular measurement with a plastic sash at the mid-axis of the body to determine the girth and volume of the body.

Wing length: Measured from the flexural line of the wing up to the longest primary feather.

Tarsus length: Known from the tibio-tarsal articulation to the base of the toes, thus giving information about the bird's leg length and structure.

Tail Length: Measured along a vertical plane from the base of the tail to the most extreme point on the longest feather, including data on the relative size and form of the tail.

Wingspan: This refers to the overall wingspan, which in this case is the distance between the tips of the wings when stretched out.

Beak length: A critical measurement, which is most useful in the study of feeding adaptations and behavior; the measurement is taken from the base of the beak through to the tip.

Body length: From the beak down to the extremity of the tail feathers on the tip of the tail, with an overall length measurement of the bird's body.

Qualitative Assessments

These assessments were based on the color appearance of diverse components of the birds.

Primary feathers: These are especially renowned for their vibrant colored plumage and patterns. Indian crows have mostly black upper parts with iridescent blue reflections, while having black wings with large white patches on the primary feathers.

The secondary feathers were noted for their coloration and were only recorded in the observed condition. The Indian crow exhibits a glossy black appearance.

Retrices (tail feathers): Have a distinctive coloration and texture in different avian species.

Alula (Bastard wing): Color noted, generally of the primary and secondary from the feathering.

Beak: Any specific color and the markings observed are recorded.

Eye ring: The color of the skin surrounding the eyes, but is not covered by the eyelid.

Fig. 2 shows a representative of the above measurements.

Fig. 2: Display images of some of the quantitative and qualitative measurements taken on the samples of the Indian crow. A) whole body measurement with a sensitive digital scale, B) measuring wing span, C) body length, D) beak length, and E) qualitative observation of the primary and secondary feathers.

Anatomical Examination of Sexing

The sex of the captured bird was determined using phenotypic appearance and gross morphological features of the reproductive organs to identify males and females, following the standard procedure described earlier. For consistency, the sexing was performed by two investigators familiar with bird sexing. Where the sex of the bird was questionable and problematic to identify, it was referred to as unknown.

Data Analysis

The physical attributes measured were compared between genders and across diverse regions of Oman. The data generated were subjected to descriptive statistics prior to gender and regional comparison. The parametric data sets were tested for normality; the data were found to be normally distributed prior to comparison. An independent sample t-test was conducted for weight, body width, body circumference, wing length, tarsus length, wingspan, beak length, and body length by gender. For the quantitative measurements between the different governorates in Oman, an analysis of variance (ANOVA) test was used for comparison, followed by Tukey's post-hoc pairwise comparison. A significant difference was considered at $P<0.05$. The comparison of color attributes in the qualitative data was conducted using contingency tables and Chi-square tests, revealing patterns of coloration and density concerning the sexes and zones in Oman.

RESULTS

The Phenotypic Color Appearance of the Body Surface and Quantitative Measurements of the Indian Crow in the Sultanate of Oman

Table 1 presents the descriptive statistics of the phenotypic characteristics of the Indian Crow. The color of the primary, secondary, and tail feathers, as well as the alula, beak, back, and eye ring, was predominantly black (100.0%), with only one exception in the eye ring (99.7% black, 0.3% blue). The belly color was mostly black (99.5%), with a small proportion being dark grey (0.5%). The chest color showed more variation, with 98.9% grey and 1.1% black, while the forehead was predominantly black (99.7%), with a minor occurrence of grey (0.3%). Sample types included whole carcass (39.9%), internal organs (25.7%), feathers (31.2%), and droplets (3.3%).

Table 1: The Phenotypic Color Appearance of the Body Surface of the Indian Crow in the Sultanate of Oman

Variables		Frequency	Percentage
Color of Primary feathers	Black	367	100.0
Color of Secondary feathers	Black	367	100.0
Color of Retrice (Tail)	Black	367	100.0
Color of Alula	Black	367	100.0
Color of Beak	Black	367	100.0
Color of Eye Ring	Black	366	99.7
	Blue	1	0.3
Color of Back	Black	367	100.0
Color of Belly	Black	365	99.5
	Dark Grey	2	0.5
Color of Chest	Black	4	1.1
	Grey	363	98.9
Color of Forehead	Black	366	99.7
	Grey	1	0.3
Samples	Whole Carcass	366	39.9
	Internal Organs	236	25.7
	Feathers	286	31.2
	Droplets	30	3.3

The mean weight of the Indian Crow was 261.54±38.61grams. Other measurements included a body width of 4.82±0.45mm, body circumference of 16.63±1.14mm, wing length of 31.52±1.80mm, tarsus length of 4.62±0.35mm, wingspan of 75.14±3.57mm, beak length of 4.98±0.39mm, and body length from beak to tail of 39.09±2.10mm (Table 2).

Comparison of Phenotypic Characteristics (Quantitative Measurements) of Indian Crow across Gender

Table 3 presents the findings of an independent sample t-test comparing the phenotypic characteristics of male and female Indian Crows. Significant differences were found across all measured traits. Males had a significantly higher mean body weight when compared to females (P<0.001). The body width was also greater in males than in females (P<0.01). Similarly, males possessed a larger body circumference than females (P<0.001). The tarsus length was also greater in males than in females (P<0.001).

Additionally, males exhibited a larger wingspan than females (P<0.001). The beak length was longer in males (P<0.001). The body length from beak to tail was greater in males than in females (P<0.001). These findings indicate significant sexual dimorphism in the phenotypic characteristics of Indian Crows.

Table 2: The Quantitative Measurements of the Indian Crow in the Sultanate of Oman

Quantitative measurements	Mean±SD
Weight (g)	261.54±38.61
The body width (cm)	4.82±0.45
The body circumference (cm)	16.63±1.14
The wing (cm)	31.52±1.80
Tarsus (cm)	4.62±0.35
The wingspan (cm)	75.14±3.57
Beak length (cm)	4.98±0.39
The length of the body (from the beak to the tail) cm	39.09±2.10

Table 3: Independent sample T-test for Phenotypic Characteristics of Indian Crow Across Gender in the Sultanate of Oman

Variables	Gender	N	Mean	Level of significance
Weight (g)	Male	169	277.61±41.49	***
	Female	200	250.35±31.38	
The body width (mm)	Male	169	4.90±0.51	**
	Female	200	4.76±0.39	
The body circumference (mm)	Male	169	16.99±1.17	***
	Female	200	16.34±1.04	
The wing (mm)	Male	169	31.84±1.79	**
	Female	200	31.31±1.80	
Tarsus (mm)	Male	169	4.73±0.37	***
	Female	200	4.54±0.32	
The wingspan (mm)	Male	169	75.99±3.83	***
	Female	200	74.47±3.21	
Beak length (mm)	Male	169	5.09 ± 0.35	***
	Female	200	4.88±0.40	
The length of the body (from the beak to the tail) in mm	Male	169	39.78±1.92	***
	Female	200	38.53±2.13	

**P<0.01, ***P<0.001.

Comparison of Phenotypic Characteristics of Indian Crow across the Governorate

Table 4 presents the results of an ANOVA comparing the phenotypic characteristics of Indian Crows across four governorates: Dhofar, Muscat, North Batinah, and South Sharqiyah. Significant differences were found for several traits. The mean weight differed significantly among governorates, with Dhofar crows weighing the highest and North Batinah crows having the lowest body weight. Body width also varied significantly, with Dhofar crows having the largest body width compared to North Batinah crows. Significant differences were found in body circumference (P<0.01), with Dhofar crows having the largest circumference and South Sharqiyah crows having the lowest. Tarsus length differed significantly, with Dhofar crows having the longest tarsus and North Batinah crows having the shortest. Wingspan also showed significant variation (P<0.01, with Dhofar crows having the largest wingspan and North Batinah crows having the lowest. Beak length differed significantly across governorates, with Dhofar crows having the longest beaks compared to North Batinah crows. No significant differences were found for wing length (P>0.05) or body length from beak to tail (P>0.05). These findings indicate significant regional variation in several phenotypic traits of the Indian Crow, particularly in weight, body width, body circumference, tarsus length, wingspan, and beak length.

Cross Tabulation of Phenotypic Characteristics Across Gender and Governorate

Across all cross-tabulations, there were no significant associations between gender and the phenotypic characteristics of eye ring color, belly color, chest color, or forehead color. This indicates that the distribution of

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these phenotypic characteristics is not significantly different Across genders in the studied population of Indian Crows. There was no significant association found regarding the color of the eye ring by governorate. The color of the belly, chest and forehead by governorate has no significant association.

Table 4: Comparison of Phenotypic Quantitative Traits of Indian Crow Across the Governorate

Variables		N	Mean±SD	Level of significance
	Dhofar	77	286.92±30.91	***
	Muscat	133	270.84±42.39	
Weight (g)	North Batinah	82	240.45±28.20	
	South Sharqiyah	77	242.59±25.61	
Body width (mm)	Dhofar	77	5.10±0.42	***
	Muscat	133	4.87±0.49	
	North Batinah	82	4.60±0.32	
	South Sharqiyah	77	4.68±0.35	
Body circumference (mm)	Dhofar	77	17.01±1.11	**
	Muscat	133	16.70±1.15	
	North Batinah	82	16.52±1.05	
	South Sharqiyah	77	16.23±1.12	
Wing (mm)	Dhofar	77	31.50±1.60	NS
	Muscat	133	31.26±1.75	
	North Batinah	82	31.94±2.19	
	South Sharqiyah	77	31.55±1.56	
Tarsus (mm)	Dhofar	77	4.70±0.32	***
	Muscat	133	4.66±0.31	
	North Batinah	82	4.44±0.38	
	South Sharqiyah	77	4.68±0.38	
Wingspan (mm)	Dhofar	77	75.57±3.77	**
	Muscat	133	74.56±3.37	
	North Batinah	82	74.53±3.91	
	South Sharqiyah	77	75.46±2.95	
Beak length (mm)	Dhofar	77	5.13±0.43	***
	Muscat	133	5.00±0.37	
	North Batinah	82	4.84±0.43	
	South Sharqiyah	77	4.93±0.23	
Length of the body (from beak to the tail) mm	Dhofar	77	39.48±2.26	NS
	Muscat	133	38.76±2.38	
	North Batinah	82	39.27±1.81	
	South Sharqiyah	77	39.07±1.57	

** P<0.01, *** P<0.001, NS not significant.

DISCUSSION

The study was undertaken with the primary objective of comprehensively characterizing the morphological features of the Indian Crow as an invasive avian species in the Sultanate of Oman. This bird has been reported to be common in and around Delhi, India (Nadhairi et al., 2024; Daniels, 2025). In particular, the emphasis is to record the morphometric features of these species in various governorates, to compare the given phenotypic parameters between genders, to investigate geographical polymorphism in these parameters in different populations, and to contribute to the creation of a baseline for future genotypic analyses in order to develop strategies and measures for the eradication of these species in future as reported by Puttoo and Archer (2004) and Yong et al. (2024).

The findings from this study revealed a standard chromatic pattern regarding the feathering. The primary, secondary, rectrices, or tail and even the alula feathers are dominantly black. The beak, back, and eye ring are primarily configured in black, with minor variations including blue in the eye ring and grey in the belly. This indicates that these traits have either tight genetic regulation or have experienced minimal selective pressure for variation, as reported by Fraser et al. (2015) and Krzemińska et al. (2016). All the anthropometric characters of the Indian Crow are higher in males than in females, illustrating the substantial sex differences. There were also differences across the regions, with crows of Dhofar being heavier and bigger than those in other regions, which may be due to environmental factors like food availability and habitat types (Nijman et al., 2022).

On the other hand, the observed differences in sizes and weights across regions indicate that local environmental factors played a significant role in the morphological differentiation of these birds. Knowledge of all these morphological features could be essential for the easy identification of the adaptive measures, ecological roles, and the potential for the management and conservation of these invasive species within Oman (Fiorini et al., 2022). One striking feature of the Indian crows in Oman is that all their feathers have the same color. The head, tail, wing, and half of the back were predominantly black with slight variation; the primary, secondary, and rectrices (tail feathers), as well as the alula, beak, back, and eye ring, were black. This could mean there is tight genetic control over feather coloration or a lack of selective pressures for variation in these aspects. This study also confirms a similar phenotypic trend, as 98.9% of the chest area samples were grey, which may be particular to this population.

The mean weight was 261.54g, yet with a certain degree of variance as indicated by standard deviations. Other measurements, such as the body width, body circumference, wing length, tarsus length, wingspan, beak length, and body length from beak to tail, also exhibit the same trend in terms of variability. These measurements are important indices of the degree of physical adaptation of the birds to the environmental conditions of the area inhabited by the Indian Crows. Males were observed to be larger than females, with notable variations in all the corresponding parameters. Males were significantly heavier than females in weight, width, circumference, wing length, tarsus length, wingspan, beak length, and body length from beak to tail. These differences are statistically significant with P<0.001 for all traits between males and females, suggesting a high level of sexual dimorphism among this species as reported by Hameed et al. (2014).

The variation in the size of males and females could also be due to territorial dominance, displays, or other activities that may be essential in the reproduction process, as reported by Hameed et al. (2014). On the other hand, the females might be smaller due to certain selective factors related to egg-laying and nesting activities. The analysis of variance (ANOVA) indicated a statistically significant variation in a few phenotypic characteristics between governorates. Crows caught in the Dhofar region were comparatively heavier, and their body width, body circumference, tarsus length, wingspan, and beak length were also larger in size. These differences could be attributed to environmental factors such as the type of food, climate, and habitat in which the animals live, all of which vary across Oman. These regional differences might

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be due to adaptation to local conditions, where the Indian Crows appear to exhibit remarkable ecological plasticity. The increased body weight and size of the Dhofar crow may be attributed to the availability of higher-quality food resources or favorable climatic conditions. Perhaps vegetation and food resources are scarce in North Batinah or other inhibiting factors force the growth to be considerably small. Thus, the variability of ecological factors in different regions underlined the significance of adaptations in the experience of Indian Crows.

Chi-square tests for gender or governorate, using the colors of the eye ring, belly, chest, and forehead, found no correlation. This indicates these particular phenotypic characteristics are uniform across both genders and regions. The relative stability of these traits suggests they are not subject to variable selective pressures from gender or geographical location. Other attributes, like genetic predispositions, may be more influential in defining such qualities.

The findings of this study depicted homogeneity in the color of the feathers —primary, secondary, rectrices, and alula—as predominantly black, which supports earlier observations made regarding low-level phenotypic variation in the species (Alonso et al., 2009). Thus, minor deviations like the small percentage of blue in the eye ring and dark gray in the belly indicate strict hereditary control of these characteristics. Such uniformity in coloration is explained by either stabilizing selection for this particular coloration or a lack of selective pressures against variation, which correlates with findings from other studies on invasive species that have adapted well to a new environment. Larger males likely have a greater ability to defend territory and perform leg mating, whereas the size of females may be strategically advantageous for nest-making and egg-laying. Overall, these differences, all statistically significant across measured traits, provide a comprehensive picture of sexual dimorphism in the species.

The pronounced variations in morphological traits displayed by Indian Crows across geographical regions, particularly the greater weight and size of crows from the Dhofar governorate, indicate the influences of factors such as food and climate. This supports earlier research demonstrating that local adaptation is pivotal to the survival and fitness of birds (Iqbal et al., 2022; Kumar et al., 2023). These variations must be the result of an adjustment to factors such as the availability of superior foods or a more favorable climate in those regions. Conversely, the diminutive size of crows in North Batinah may signify unfavorable environmental factors diminishing the availability of food resources or both, thus substantiating the assertion that environmental factors are accountable for morphological variation (Khvatov et al., 2021; Charpentier et al., 2023), The absence of statistical correlations between the coloration of the eye ring, belly, chest or forehead and the gender or governorate in both species further suggests that these phenotypic traits are randomly distributed across the genders and regions. This lack of significant differences implies that these characteristics are not subject to extreme differential selective constraints about gender or geographical area. These traits can be genetically determined, which aligns with the existing literature on the genetic foundations of phenotypes in birds (Bicho & Esteves, 2022; Gayo & Ngongolo, 2024).

The disparities in size and weight across regions suggest that local habitat conditions play a pivotal role in selecting these morphological traits, demonstrating that invasive species are adaptable in adjusting to diverse environments (Patankar et al., 2021; Kumar & Ojha, 2022). Therefore, to investigate the bio-social aspects and bio-geographical distribution of the species, it is imperative to identify these morphological features by examining nesting and roosting mechanisms (Gaudry et al., 2017; Benmazouz et al., 2023). When any of these changes occur, including variations in climate, increases in human settlement, and changes in habitats, they may cause a corresponding change in the phenotypes of the Indian Crows (Iqbal & Said, 2025). Such changes can assist conservationists in predicting and mitigating unfavorable effects on crow populations (Hasuia et al., 2024). For example, if it is established that certain aspects of an organism's physiology are beneficial when the population's environment is altered, then these aspects can be safeguarded or even improved.

Conclusion

The Indian Crow flight feather design was highly chromatically integrated, with primary, secondary, tail, and alula feathers mainly black in color. Minor changes included blue in the eye ring and grey in the belly. This suggests either strong genetic regulation of feather coloration or little selection pressure on different colorings. The morphometric differences revealed that males are significantly larger than females, indicating high levels of sexual size dimorphism within this species. Behaviors such as reproduction and territoriality are likely influential factors. The study results showed that birds from Dhofar had larger and heavier beaks compared to those from other regions. It can be easily presumed that environmental factors, such as food abundance and climatic conditions, play a crucial role in determining these traits in birds. This regional variation demonstrates that the Indian Crow has adapted to variations in climatic conditions, hence the influence of local habitat conditions on morphological measures.

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In Press

Conflict of Interest: The authors declare no conflicts of interest.

Data Availability: The data generated from this study are available from the corresponding author upon reasonable request, provided it will be used judiciously.

Ethics Statement: This study was conducted in parallel with the national invasive bird control program, organized by Environmental Authority of Oman, which aims to manage and reduce the population of invasive bird species in Oman. As part of this initiative, the control team culled Indian crows using air rifles following approved protocols. The collected specimens were then sent to the laboratories of A'Sharqiyah University for research purposes under the framework of the collaborative research project. Ethical approval for this study was obtained from the Environment Authority of the Sultanate of Oman and institutional animal care and use committee of A'Sharqiyah University (ASU), Oman (Ref. no: CP/ENV/ASU/2023/0). Prior to the commencement of the fieldwork, an approval request was submitted and granted. All procedures related to the collection, handling, and laboratory analysis of bird samples adhered to international ethical guidelines for wildlife research, ensuring compliance with humane culling methods and responsible scientific use of specimens, as outlined by Morris and Parsons (2023). Additionally, the study complied with national regulations governing wildlife research and conservation efforts, ensuring that all activities were conducted responsibly and ethically.

Author's Contribution: QA, AA and MA were involved in the initial conceptualization of the project. QA, KMK and AA partake in supervision and monitoring of the field works. The laboratory work was conducted by MA, TA, BA, JA and MA. QA and AAA performed the initial draft of the manuscript. Statistical analysis was conducted by QA, AA and AAA. All authors read and reviewed the manuscript before submission.

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