VOLUME 9 ISSUE 2 2023

ISSN 2454 – 3055

INTERNATIONAL JOURNAL OF ZOOLOGICAL INVESTIGATIONS

Forum for Biological and Environmental Sciences

Published by Saran Publications, India

International Journal of Zoological Investigations Vol. 9, No. 2, 849-858 (2023)

International Journal of Zoological Investigations

Contents available at Journals Home Page: www.ijzi.net

Editor-in-Chief: Prof. Ajai Kumar Srivastav

Published by: Saran Publications, Gorakhpur, India

ISSN: 2454-3055

Nesting Behaviour and Calcium Carbonate Content in Eggshells of Different Birds: A Review

Chavan Akash and Chondekar Ramesh*

Department of Zoology, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad, Maharashtra, India

**Corresponding Author*

Received: 9th August, 2023; **Accepted:** 15th September, 2023; **Published online:** 11th October, 2023

https://doi.org/10.33745/ijzi.2023.v09i02.095

Abstract: Birds are one of the important indicators of the state of the environment and changes in bird populations are often the first indication of environmental problems. Hence, the health of these birds is very important. Working on nesting material and nesting behaviour of different birds, we can find new approaches for the conservation of the different bird species. Another vital aspect of birds' health is the $CaCO_3$ proportion in their eggshell, which is a good indicator of a healthy environment. Hence, by working on the $CaCO_3$ content of eggshells of the birds of different areas, we can monitor different areas. This will help in creating a protocol to identify proper methods to assess the health of the ecosystem in which we live. Furthermore, we examine the potential links between nesting behaviour and the variation in calcium carbonate content, investigating how nest site selection, nest lining, and nest architecture may influence the deposition of calcium in the eggshell matrix. Additionally, this review discusses the implications of altered nesting behaviour and shifts in calcium carbonate availability due to anthropogenic influences such as habitat destruction, climate change, and pollution. Understanding these potential impacts is crucial for assessing the reproductive success and population dynamics of various bird species in the face of ongoing environmental changes. This study provides valuable insights into the adaptive significance of nesting behaviour and the dynamic nature of eggshell composition across different avian taxa. This knowledge contributes to the conservation efforts and management strategies aimed at preserving the reproductive success and overall health of avian populations in the midst of a changing world.

Keywords: Birds, Nesting behaviour, Nesting material, Eggshell, Calcium carbonate

Citation: Chavan Akash and Chondekar Ramesh: Nesting behaviour and calcium carbonate content in eggshells of different birds: A review. Intern. J. Zool. Invest. 9(2): 849-858, 2023.

https://doi.org/10.33745/ijzi.2023.v09i02.095

Introduction

Nesting behaviour and the calcium carbonate content in eggshells are both fascinating aspects of avian biology. Nesting behaviour refers to the instinctive actions and behaviours exhibited by animals to build a nest or a shelter for various purposes, such as reproduction, protection, and raising offspring. Nesting is commonly observed among birds, but it can also be found in other

animal groups such as mammals, reptiles, and insects. They are constructing a nest for laying their eggs and/or raising their offspring. Many bird species build a nest to ensure a safe and stable microclimate for the development of their young (Hansell, 2000). A well-constructed nest helps to protect their eggs from extrinsic factors like heat, cold, humidity, and predation. Building a nest can conserve energy for later stages of parental care which result in healthier offspring and higher reproductive output (Reid *et al*., 2000; Mainwaring and Hartley, 2013). Birds construct their nest from a variety of materials which can be natural or man-made such as leaves, twigs, branches of trees, thread part of grass, plastic, mud pellets, small stones, etc. (Achegawe *et al*., 2016). The process of nest construction is an energetically expensive process (Mainwaring and Hartley, 2013). Hence, birds collect these nesting materials from nearby areas for minimizing the energy requirement. Another important aspect of breeding birds is the calcium carbonate content in their eggshell because the majority content of eggshells is calcium carbonate ($CaCO_3$). Deficiency of calcium during breeding periods of birds results in poor eggshell formation and young birds can be unhealthy or sometimes hatchlings never hatch and die before hatching (Alavandi *et al*., 2018). This can lead to the declining population of that bird species due to which the population of birds can become endangered or even birds that are already endangered may face extinction in the near future (Gilbert *et al*., 2002). Overall, studying nesting behaviour and the calcium carbonate content in bird eggshells provides insights into avian ecology, reproduction, and evolutionary adaptations. Researchers should continue to investigate these topics to understand the diverse strategies and adaptations of different bird species in their nesting habits and reproductive biology.

International Status of Research on Nesting Behaviour of Birds:

Nesting behaviour plays a crucial role in the reproductive success of birds. The way birds build their nests, select nest sites, and care for their eggs and nestlings can significantly impact their ability to successfully reproduce (Hatchwell *et al*., 1999). By understanding the specific nesting requirements of different bird species, conservationists can create and manage habitats that support successful breeding. For example, identifying preferred nest sites or the types of materials birds use for nest construction, can be useful for land management practices and conservation strategies. Nesting behaviour studies also help uncover important ecological relationships between birds and their environment. Birds interact with their surroundings while selecting nest sites, foraging for nest materials, and defending their nests (Di Santo *et al*., 2017). By understanding how birds interact with their habitat, researchers gain insights into broader ecological processes, such as competition for resources, predator-prey dynamics, and impacts of environmental changes on bird populations. Nesting behaviour provides valuable information for evolutionary research (Perez *et al*., 2020). Different bird species exhibit a wide variety of nest types, from simple scrapes on the ground to intricate structures built in trees or cliffs (Collias, 1964). By studying nesting behaviours across bird families, researchers can investigate the evolutionary origins and adaptations of nesting strategies and understand how they have evolved over time.Worldwide, many researchers studied the nesting behaviour of different birds such as Collias and Collias (1962), conducted research on the mechanism of nest building in weaver birds, and found that weaver birds use their beaks to stitch nesting material.Weaverbird uses stitching, knotting, and weaving actions during the building of its nest and the woven design of the entrance tube has interlacement of two sets of yarns which provides the best resistance against the shear stress. It can be inferred that the weaving concept of present-day plain fabric may have developed by mimicking the construction mechanism used by weaverbirds. Nelson (2002) reported that the use of synthetic fibres as nesting material is a common strategy among gannets and Hartwig *et al.* (2007) stated

that other species of seabirds use plastic debris to line their nests. Walsh *et al.* (2009) conducted research on the repeatability of nest morphology in African weaver birds and conclude that male Southern masked weaver birds have low but significant repeatability of nest morphology and in village weavers, there is no significant repeatability of nest morphology. Votier *et al.* (2011) studied how seabirds use plastic material for nest building and reported that breeding gannets collect large quantities of plastic of marine origin to use as nesting material. This plastic material can become entangled around the legs, feet, and sometimes wings of both adult and nestling gannets, which would result in the death of some gannets. Hosseini-Moosavi *et al*., (2013) observed that Eurasian Collared Dove prefers *Ziziphus numullaria* as a nesting tree. Mainwaring and Hartley (2013) emphasized that nest construction is an energetically expensive process and they give some pieces of evidence which prove that avian nest building is an energetically and temporally expensive activity. Although birds spend a significant amount of energy and time in the construction of their nests and maintenance (Hansell, 2000; Stanley, 2002), one of the important aspects of the avian life cycle i.e., the nesting behaviour of birds has been ignored by the researchers in comparison to other aspects of the breeding biology of birds (Deeming and Reynolds, 2015). Saurez-Rodriguez *et al.* (2013) reported that some birds living in cities use cigarette butts in their nests. They concluded that butts from smoked cigarettes retain some amount of nicotine and other compounds may acts as arthropod repellents and the amount of cellulose acetate contained in butts is negatively correlated with the number of parasites in the nest. Mainwaring *et al.* (2014) studied the design and function of birds' nests and found that sexual selection influences nest design. They also inferred that nest design also varies adaptively to overcome the harmful effects of parasites and they make a suitable microclimate for developing offspring in relation to predictable variation in environmental conditions. In today's world which is going rapidly towards urbanization, some birds also called urban birds have adapted to urban environments but the process of urbanization also involves irretrievable replacement of natural rural habitats like woodland, farmland, etc. with concrete jungles containing parks, gardens, etc. (Forman, 2014; Shanahan *et al.,* 2014). Awais *et al.* (2015) observed that House Crow favoured to build nests on *Vachellia nilotica, Populus alba* and *Eucalyptus globulus*. Biddle *et al.* (2017) observed the construction patterns of birds' nests which explains the nest-building behaviours of birds and they hypothesized that materials used for nest buildings in the different parts of nests have different functions which suggests that positioning of particular materials in nests may not be random. van der Hoek *et al.* (2017) studied the diversity, distribution, and conservation status of the tree-cavity nesting birds. Globally, at least 338 species of birds use cavities created by woodpeckers and at least, 1878 species, which is 18.10% of all bird species in the world, use tree cavities for nest building. About 13% of tree-cavity nester experiences major threats thus global conservation priority should be the maintenance of tree cavities because it provides important nesting sites for many bird species.

According to Moreira *et al.* (2018), anthropogenic structures have negative impacts on wildlife population but they can be beneficial also as power lines are one of the main causes of bird mortality through collisions but electricity pylons are used for nest building by some bird species like White Storks. They concluded that there were 668 (7.70%) pylons out of a total of 8660 pylons, White Storks nests in Portugal. Cesar *et al*. (2018) discovered that a new species of *Gymnopus* with rhizomorphs were used as nesting material by *Myonectes oleaginous* (Tyrannidae) which is the bird species inhabiting the subtropical cloud forest. Leniowski and Wegrzyn (2018) conducted research on the synchronization of parental behaviours to reduce the risk of nest predation in a socially monogamous passerine bird and inferred that mates synchronize their behaviours to reduce total activity at the nest

which affects the predation rate in birds. According to Biddle *et al.* (2018), birds are unaware of the structural properties of the nesting material which is used by them but they judge the mass and diameter of that nesting material when they pick it by their beak and by using this information, they determine which piece is fit for the appropriate stage of nest building. Although many studies have been done which show a significant change in the material used by birds for their nest construction due to urbanization (Wang *et al*., 2009; Reynolds *et al*., 2016), some researchers are not able to find this change (Townsend and Barker, 2014; Hanmer *et al*., 2017) which suggests that the change in nest material and pattern of nest building may be species-specific or it can be area-specific. According to Wang *et al.* (2009) in urban area birds uses anthropogenic material in larger amount compared to natural things like native plants and Reynolds *et al.* (2016) observed greater use of other materials like feathers for nest construction. James *et al.* (2019) studied on urbanization and nest building in birds and concluded that urbanization leads to habitat loss and fragmentation of habitat. They also observed that changes in the nesting material used by birds such as plastic and cigarette butts which is associated with urbanization.

National Status of Research on Nesting Behaviour of Birds:

Davis (1974) observed that the birds in North-Western India prefer the *Acacia* for nesting and the breeding period of birds in this region is monsoon because of the availability of nesting fibre which comes mostly from millets and other grasses and insects to feed young. Borges (2002) studied the variation in nest-building fibres used by Baya weavers in Goa, India and found that almost all Baya weavers use fibres obtained from coconut or sugarcane leaves. They also noticed that fibres obtained from sugarcane leaves are used to build the stalk and upper part of the chamber and fibres obtained from coconut leaves are used in the construction of an egg chamber. Asokan *et al.* (2008) investigated nest construction and nest microclimate of the Baya weaver in Tamil Nadu, India and found that the bird constructed nests at palm (*Borassus flabellifer*), coconut (*Cocos nucifera*) and date palm trees (*Phoneix pusilla*) whereas the mean temperature of the nests vary from 25^{o}C to 29^{o}C and light intensity differing between 25 Lux and 625 Lux. Ali (2009) observed the nest site selection and prey delivery patterns to nestlings by the Baya Weaver in Tamil Nadu, India and by using Analysis of Variance (ANOVA) they inferred that tree height, total number of leaves, number of leaves in the middle area of tree, and number of dried leaves has significant variation between nesting and non-nesting trees and the female Baya Weaver delivered different prey items to their nestlings such as grasshoppers, caterpillars, unknown items, etc. Raju (2009) emphasizes the nesting behaviour of the Baya Weaver in the Eastern Peninsular region of India on hills distributed from Chennai North to Bhubaneshwar and concluded that the Baya Weaver bird, *Ploceus philippinus* uses the well-developed leaves of *Cycus spaerica* and *Dendrocalamus strictus* for their nest building. Narwade *et al.* (2010) conducted a survey on birds of Osmanabad in the Marathwada region and they find that the area still provides some potential habitats for the declining population of the threatened birds. According to Das (2015), the baya weaver might be a possible inspiration for human weavers because male weaverbirds construct nests by using fibrous materials stitched into each other like a weaving process. Chavan *et al.* (2016) studied breeding and morphometric characteristics of the nest and eggs of *Vanellu smalabaricus* from the Nanded region of Maharashtra. They found a low population of birds i.e., 6 pairs/20 km^2 because the Yellow-wattled Lapwing as a ground-nesting bird has no effective protection strategy to build the nest for egg laying except camouflage with the ground condition for the colour of the nest and the eggs. Achegawe *et al.* (2016) studied the nesting of Baya Weaver in SRTM University, Nanded and Fields along the Asana River at Nanded, Maharashtra, India and found 435 nests/10 km^2 on 9 plant species that

belong to 6 families and total number of host trees are 82 in which *Acasianilotica* and *A. karroo* trees were most preferred for the nest building. Radhamany *et al.* (2016) observed that in urban areas, house sparrow (*Passer domesticus*) uses anthropogenic nesting material in larger amount, while there is a reduction in the use of natural things, specifically native plants, as a nesting material. Sohi and Kler (2017) observed avian nesting behaviour in relation to indigenous trees and housing structures in Punjab and found that 10 bird species use unusual materials such as plastic pieces, animal hairs, pieces of cloth, toffee wrappers, wires, threads, safety pins and bangles as nesting material and also seen the Asian Pied Starling has constructed nests on *Ficus virens* tree, Spotted Munia on Dhek and Cheeku, Baya Weaver on Ber, Pear and *Areca Palm*. According to Gulrez *et al.* (2017) in the study area of SRTM University, Nanded there are 5 types of birds' nests found such as cup-shaped, open platform-shaped, spherical-shaped, pocket-shaped, and colonial type and nesting material used by different birds were dried grasses, twigs and branches of tree, mud, and feathers. Jadhav *et al.* (2018) also reported that birds use material available in nearby areas including synthetic materials, plant materials, soil, silt, mud, and material of animal origin like human hair, threads of spider net and dropped feathers of birds. Khan *et al.* (2020) studied host plant relationship of bird species in the Jhalawar region of Rajasthan, India and found that a total of 17 bird species build their nest on 22 different plant or tree species in which *Acacia* species is the most favoured host tree.

International Status of Research on $CaCO_3$ Content in Eggshells of Birds:

The study of the calcium carbonate content in the eggshells of birds is essential for several reasons. Calcium carbonate is the primary component of eggshells and is essential for their formation (Hunton, 2005). Calcium is required by birds to develop strong and healthy eggs (Roberts, 2004; Kakhki *et al*., 2019). By studying the calcium carbonate content in eggshells, researchers can assess the quality and health of the eggs. Higher calcium carbonate content generally indicates better reproductive success, as it contributes to the structural integrity of the eggshell, reducing the risk of breakage during incubation. The calcium carbonate content in eggshells can provide insights into the availability of calcium in the environment. Birds obtain calcium from their diet, primarily through the consumption of calcium-rich foods such as seeds, insects, and shellfish (Graveland and Van Gijzen, 1994). By analysing the calcium carbonate content in eggshells, we can evaluate the calcium availability in the birds' habitats. A decline in calcium carbonate content may indicate a decrease in the availability of calcium sources, which can have detrimental effects on bird populations. Birds play a vital role in ecosystems as indicators of overall environmental health (Gregory and van Strien, 2010). They are sensitive to environmental changes and can reflect the impact of factors such as pollution, habitat degradation, and climate change. By monitoring the calcium carbonate content in eggshells, we can identify potential environmental stressors that may affect bird populations. Declining calcium carbonate content could suggest adverse environmental conditions that may have cascading effects on other species within the ecosystem. Understanding the calcium carbonate content in eggshells can have conservation implications for bird species. It can help identify regions or habitats where calcium availability may be limiting reproductive success. That is why the study of the calcium carbonate content in the eggshells of birds is crucial for assessing reproductive success, evaluating environmental conditions, monitoring ecosystem health, and implementing effective conservation measures. By understanding the factors influencing calcium availability and its impact on bird populations, scientists can contribute to the preservation and management of avian species and their habitats. According to Romanoff and Romanoff (1949), the eggshell composition is about 98.2% Calcium carbonate and 0.9% each Magnesium and Phosphorous. Eggshell is also

comprising of a shell membrane that contains 69.2% proteins, 27.2% ash, 2.7% fat, and 1.5% moisture (MacNeil, 1997) and proteins from the shell membrane contains about 10% collagen (Froning, 1998). Many researchers studied $CaCO_3$ content in the eggshells of birds. According to Hincke *et al.* (2008) and Gautron *et al.* (1996), the colour of the eggshell also influences the calcium carbonate content in the egg shells as the dark coloured eggshell has more calcium carbonate when compared to the white coloured egg shell. Hunton (2005) proved that white-coloured eggshells have less calcium carbonate compared to brown-coloured eggshells. According to Scheideler (1998), if the combined diet of calcium from eggshells and a large-particle calcium source was given to egg-laying hens then calcium is highly available and it will support egg production. This is like the conclusion of Keshavarz *et al.* (1993) concluded that calcium sources with low *in vitro* solubility are needed in layer rations to improve shell quality. Eeva and Lehikoinen (1998) conducted study on the direct and indirect effects of air pollution on two bird species pied flycatchers (*Ficedula hypoleuca*) and the great tits (*Parus major*) and found that the reduced breeding performance of birds in the polluted area has various causes like the diet of *F. hypoleuca* contains a high number of heavy metals, and this effect is enhanced by the lack of calcium-rich food and the decreased amount of invertebrate food in the polluted area was the main reason for lowered nestling production in *P. major*. Shen and Chen (2003) observed that duck eggshells have a high amount of calcium compared to chicken eggshells. James *et al.* (2004) discussed on calcium supplementation of breeding birds and stated that detecting calcium limitation is required to provide effective calcium supplementation to breeding birds. Adeyeye (2009) has done a comparative study on the characteristics of eggshells of some bird species in Nigeria and concluded that increased or decreased calcium levels in birds might be depending upon their habitat such as domestic birds are fed with supplementary feed which is why they have higher calcium content in their eggshell comparatively to the wild birds. El-Ishaq and Kida (2011) studied the comparative analysis of calcium carbonate content in eggshells of hen, duck, and guinea fowl and found that hen eggshell contains 97.8% $CaCO_3$, poultry chicken eggshell contains 96.9% $CaCO_3$, Guinea fowl eggshell contains 98.7% $CaCO_3$, and Duck eggshell contains 97.9% $CaCO_3$. According to King'Ori (2011), one teaspoon of powder can be obtained from one medium-sized eggshell which contains 750-800 mg of calcium and other microelements. Al-Obaidi *et al.* (2012) analysed inorganic elements in some wild birds in which calcium percentages were 97.3%, 97.4%, 97.8% and 97.8 % in House Sparrow, White- eared Bulbul, Collared Dove, and Rock Dove, respectively. Hincke *et al.* (2012) observed that brown coloured egg has a higher strength than white coloured egg because calcium in the brown eggshell (82.25%) is greater than white eggshell (75.82%). Kolekar *et al.* (2020) did the experimental analysis of eggshell samples and found the calcium carbonate content in the eggshell as swift eggshell- 68.06%, lapwing- 96.46%, and hybrid hen-95%. McClelland *et al.* (2021) concluded that eggshell $CaCO_3$ content is greater in birds with thinner eggshells in their sample of 222 bird species and proved their hypothesis that eggshell $CaCO_3$ content was positively correlated with birds possessing thinner eggshells. Umbrasko *et al.,* (2021) evaluated $CaCO_3$ content in eggshells of avian, turtles, snails and ostrich and concluded that the chemical composition of ostrich eggshells is similar to eggshells of laying hens, turtles, giant snails, or quail eggs, but the concentration of the $CaCO_3$ was highest amongst them.

National Status of Research on $CaCO_3$ Content in Eggshells of Birds:

Ravichandran *et al.* (2007) studied the effect of the hardness of drinking water on eggshell thickness and found that layers fed with calcium carbonate-containing water have thicker eggshells compared to the control group which are fed with normal drinking water. Gupta (2008) reported that less or extra intake of calcium negatively affects the

eggshell quality and calcium demand of a laying hen is 4 to 6 times greater than that of a non-laying hen hence an average of 4 g of calcium per day should be required by a layer so that good eggshell quality will maintain. Gulrez *et al.* (2017) stated that by observing the food sources utilised by birds, we can find out from where the birds get the source of calcium and they observed the spotted Dove (*Zenaida macroura*) feeds crop milk to young ones which can be the source of calcium. Alavandi *et al.* (2018) carried out a comparative study on calcium content in eggshells of different birds and inferred that the Lap wing has the highest $CaCO_3$ content i.e., 96.46%, the Hybrid hen has 95.28%, Forest Pigeon has 91%, Domestic Pigeon has 87%, Local Hen has 80%, and the swift eggshell has 68.06% of $CaCO_3$. Danes (2019) carried out a comparative analysis of calcium carbonate content for eggshells of hens from the house and found that two samples of Hen eggshells from home have 92.92% and 92.58% $CaCO_3$, while the two samples of hen eggshells collected from shops have 97.83% and 96.67% $CaCO_3$. Ajayan *et al.* (2020) observed the calcium carbonate content from eggshells of various varieties of chickens as well as ducks and concluded that the average percentage of $CaCO_3$ in chicken varieties is 89.05% whereas the duck varieties have less amount of $CaCO_3$ which is 84.63%.

Conclusion

Nesting behaviour and calcium carbonate content in the eggshells of birds provides valuable insights into various aspects of avian biology and ecology. By examining the relationship between nesting behaviour and eggshell composition, we can gain a deeper understanding of reproductive success, environmental indicators, ecosystem health, and conservation implications. The nesting behaviour of birds, including nest site selection, construction, and incubation, directly influence the conditions in which eggs are laid and developed. By studying nesting behaviour, we can identify factors that may impact the deposition of calcium carbonate in eggshells, such as the availability of suitable nesting materials and the protection provided by the nest structure. The calcium carbonate content in eggshells serves as a crucial indicator of reproductive success, reflecting the health and quality of eggs. Higher calcium carbonate content generally correlates with stronger eggshells, reducing the risk of breakage during incubation and increasing the likelihood of successful hatching. Monitoring the calcium carbonate content in eggshells can help assess the overall reproductive performance of bird populations and provide important information for species conservation. Furthermore, the calcium carbonate content in eggshells also serves as an environmental indicator. Declining calcium availability in the environment can result in lower calcium carbonate content in eggshells, potentially signalling environmental stressors, habitat degradation, or pollution. These findings can help to guide conservation efforts by identifying areas where calcium availability may be limited and where habitat restoration or protection is necessary to support healthy bird populations. Overall, the study of nesting behaviour and calcium carbonate content in the eggshells of birds contributes to our understanding of avian reproductive biology, environmental health, and conservation needs.

References

Achegawe R, Chavan S, Patil P and Tarte S. (2016) Nesting of Baya Weaver (*Ploceus philippinus*) in S. R. T. M. University, Nanded and fields along Asana River at Nanded, Maharashtra, India. Int J Curr Res Acad Rev. 4: 51-60.

Adeyeye EI. (2009) Comparative study on the characteristics of egg shells of some bird species. Bull Chem Soc Ethiop. 23(2): 159-166.

Ajayan N, Shahanamol KP, Arun AU and Soman S. (2020) Quantitative variation in calcium carbonate content in shell of different chicken and duck varieties. Adv Zool Bot. 8(1): 1-5.

Alavandi S, Dhanajaya, Shravana Kumara SM and Ananda (2018) Comparative study on calcium content in eggshells of different birds. Int J Zool Stud. 3(4): 31-33.

Ali AMS. (2009) Studies on nest-site selection and prey delivery patterns to nestlings by the Baya Weaver

Ploceus philippinus (Aves: Passeriformes) in Tamil Nadu, South India. World J Zool. 4(4): 308-312.

Al-Obaidi FA, Mehdi BI and Al-Shadeedi SM. (2012) Identification of inorganic elements in egg shell of some wild birds in Baghdad. Adv Appl Sci Res. 3: 1454-1458.

Asokan S, Ali AMS and Nagarajan R. (2008) Studies on nest construction and nest microclimate of the Baya weaver, *Ploceus philippinus* (Linn.). J Environ Biol. 29(3): 393.

Awais M, Ahmed S, Mahmood S, Mahmood T and Alvi H. (2015) Breeding biology of the house crow *Corvus splendens* at Hazara University, Garden Campus, Mansehra, Pakistan. Podoces 10(1): 1-7.

Biddle LE, Deeming DC and Goodman AM. (2018) Birds use structural properties when selecting materials for different parts of their nests. J Ornithol. 159: 999-1008.

Biddle L, Goodman AM and Deeming DC. (2017) Construction patterns of birds' nests provide insight into nest-building behaviours. PeerJ. 5: e3010.

Borges SD, Desai M and Shanbhag AB. (2002) Selection of nest platforms and the differential use of nest building fibres by the Baya weaver, *Ploceus philippinus* Linnaeus 1766. Tropical Zool. 15(1): 17-25.

César E, Bandala VM, Montoya L and Ramos A. (2018) A new *Gymnopus* species with rhizomorphs and its record as nesting material by birds (Tyrannideae) in the subtropical cloud forest from eastern Mexico. MycoKeys 42: 21-34.

Chavan S, Achegawe R and Padghane S. (2016) Characters of nesting site, ground nest and eggs of Yellow-wattled Lapwing *Vanellus malabaricus* (Aves: Charadridae). Int J Zool Stud. 1(6): 12-17.

Collias NE. (1964) The evolution of nests and nest-building in birds. American Zool. 4(2): 175-190.

Collias NE and Collias EC. (1962) An Experimental study of the mechanisms of nest building in a Weaverbird. The Auk 79(4): 568-595.

Danes Dhanush B. (2019) Comparative analysis of eggshell's calcium carbonate content collected from home and shop. Res Rev Int J Multidiscipl. 4(4): 874-876.

Das S, Bhowmick M, Chattopadhyay SK and Basak S. (2015) Application of biomimicry in textiles. Curr Sci. 109(5): 893-901.

Davis TA. (1974) Selection of nesting trees and the frequency of nest visits by Baya Weaverbird. J Bombay Natural Hist Soc. 71(3): 356-366.

Deeming DC and Reynolds SJ. (2015) Nests, eggs, and incubation: new ideas about avian reproduction. Oxford University Press, USA.

Di Santo M, Battisti C and Bologna MA. (2017) Interspecific interactions in nesting and feeding urban sites among introduced Monk Parakeet (*Myiopsitta monachus*) and syntopic bird species. Ethology Ecol Evol. 29(2): 138-148.

Eeva T and Lehikoinen E. (1998) Local survival rates of the pied flycatchers (*Ficedula hypoleuca*) and the great tits (*Parus major*) in an air pollution gradient. Ecoscience 5(1) 46-50.

El-Ishaq A and Kida HD. (2011) Comparative analysis of calcium carbonate content in eggshell of hen, duck, and guinea fowl. Iraon 3: 81-87.

Forman RT. (2014) Urban ecology: science of cities. Cambridge University Press, pp. 462.

Froning GW. (1998) Recent advances in egg products research and development. University of California Egg Processing Workshop. Riverside and Modesto, CA, USA, June 2-3.

Gautron J, Bain M, Solomon S and Nys Y. (1996) Soluble matrix of hen's eggshell extracts changes in vitro the rate of calcium carbonate precipitation and crystal morphology. British Poul Sci. 37(4): 853-866.

Gilbert M, Virani M, Watson R, Oaks J, Benson P, Khan A, Ahmed S, Chaudhry J, Arshad M, Mahmood S, Shah QA. (2002) Breeding and mortality of Oriental White-backed Vulture *Gyps bengalensis* in Punjab Province, Pakistan. Bird Conserv Int. 12(4): 311-326.

Graveland J and Van Gijzen T. (1994) Arthropods and seeds are not sufficient as calcium sources for shell formation and skeletal growth in passerines. Ardea 55(1-2): 299-314.

Gregory RD and van Strien A. (2010) Wild bird indicators: using composite population trends of birds as measures of environmental health. Ornithol Sci. 9(1): 3-22.

Gulrez S, Chavan SP, Puri D and Poul S. (2017) Nest characters, nesting success and parental care in some birds at Swami Ramanand Teerth Marathwada University, Nanded, Maharashtra. Int J Fauna Biol Stud. 4(6): 11-19.

Gupta L. (2008) Factors influencing shell quality. https://www.thepoultrysite.com/articles/factors-influencing-shell-quality.

Hanmer HJ, Thomas RL, Beswick GJ, Collins BP and Fellowes MD. (2017) Use of anthropogenic material affects bird nest arthropod community structure: influence of urbanisation, and consequences for ectoparasites and fledging success. J Ornithol. 158: 1045-1059.

Hansell M. (2000) Bird nests and construction

behaviour. Cambridge University Press. https://doi.org/10.1017/CBO9781139106788

Hartwig E, Clemens T and Heckroth M. (2007) Plastic debris as nesting material in a Kittiwake- (*Rissa tridactyla*)-colony at the Jammerbugt, Northwest Denmark. Mar Pollut Bull. 54(5): 595-597.

Hatchwell BJ, Russell AF, Fowlie MK and Ross DJ. (1999) Reproductive success and nest-site selection in a cooperative breeder: effect of experience and a direct benefit of helping. The Auk 116(2): 355-363.

Hincke MT, Nys Y, Gautron J, Mann K, Rodriguez-Navarro AB and McKee MD. (2012) The eggshell: structure, composition and mineralization. Frontiers Bioscience-Landmark 17(4): 1266-1280.

Hincke MT, Wellman-Labadie O, McKee MD, Gautron J, Nys Y and Mann K. (2008). Biosynthesis and structural assembly of eggshell components. In: Egg Bioscience and Biotechnology, (ed.) Mine Y., John Wiley and Sons, Hoboken, USA.

Hosseini-Moosavi SM, Behrouzi-Rad B, Karimpour R and Nasab SMA. (2013) Breeding biology of collared dove (*Streptopelia decaocto*) in Khuzestan province, southwestern Iran. Khouzestan Sci Res. 22(1): 51-54.

Hunton P. (2005) Research on eggshell structure and quality: an historical overview. Brazilian J Poultry Sci. 7: 67-71.

Jadhav M, Chavan S and Patange P. (2018) Nests and nest materials of birds in SRTM University area at Nanded, Maharashtra State. Int J Fauna Bio Stud. 5(2-C): 140-147.

James Reynolds S, Ibáñez-Álamo JD, Sumasgutner P and Mark CM.(2019) Urbanisation and nest building in birds: a review of threats and opportunities. J Ornithol. 160: 841-860.

James Reynolds S, Mänd R and Tilgar V. (2004) Calcium supplementation of breeding birds: directions for future research. Ibis 146(4): 601-614.

Kakhki RAM, Heuthorst T, Mills A, Neijat M and Kiarie E. (2019) Interactive effects of calcium and top-dressed 25-hydroxy vitamin D_3 on egg production, egg shell quality, and bones attributes in aged Lohmann LSL-lite layers. Poultry Sci. 98(3): 1254-1262.

Keshavarz K, Scott ML and Blanchard J. (1993) The effect of solubility and particle size of calcium sources on shell quality and bone mineralization. J Appl Poultry Res. 2(3): 259-267.

Khan F, Sharma A and Maurya IB. (2020) Host plant relationship of birds species in Jhalawar region of Rajasthan, India. Int J Adv Res Biol Sci. 7(10): 152-155.

King'Ori AM. (2011) A review of the uses of poultry eggshells and shell membranes. Int J Poultry Sci. 10(11): 908-912.

Kolekar S, Deshmukh S, Hiwale V and Dutta A. (2020) Analyzation of calcium carbonate ($CaCO_3$) in eggshells and their applications. Int Res J Innov Engineer Technol. 4(8): 37.

Leniowski K and Węgrzyn E. (2018) Synchronisation of parental behaviours reduces the risk of nest predation in a socially monogamous passerine bird. Sci Rep. 8(1): 1-9.

MacNeil J. (1997) Separation and utilization of waste eggshell. In: Proceeding of International egg commission annual production and marketing conference. Toronto, Ontario.

Mainwaring MC and Hartley IR. (2013) The energetic costs of nest building in birds. Avian Biol Res. 6(1): 12-17.

Mainwaring MC, Hartley IR, Lambrechts MM and Deeming DC. (2014) The design and function of birds' nests. Ecol Evol. 4(20): 3909-3928.

McClelland SC, Cassey P, Maurer G, Hauber ME and Portugal SJ. (2021) How much calcium to shell out? Eggshell calcium carbonate content is greater in birds with thinner shells, larger clutches and longer lifespans. J Royal Socy Interface 18(182): 20210502.

Moreira F, Martins RC, Catry I and D'Amico M. (2018) Drivers of power line use by white storks: a case study of birds nesting on anthropogenic structures. J Appl Ecol. 55(5): 2263-2273.

Narwade S and Fartade MM. (2011) Birds of Osmanabad District of Maharashtra, India. J Threatened Taxa 3(2): 1567-1576.

Nelson B. (2002) The Atlantic Gannet. Fenix Books Limited.

Perez DM, Gardner JL and Medina I. (2020) Climate as an evolutionary driver of nest morphology in birds: a review. Frontiers Ecol Evol. 8: 566018.

Radhamany D, Das KSA, Azeez PA, Wen L and Sreekala L K. (2016) Usage of nest materials by house sparrow (*Passer domesticus*) along an urban to rural gradient in Coimbatore, India. Tropical Life Sci Res. 27(2): 127.

Raju AJS. (2009) Nesting behaviour of the Baya Weaver bird, *Ploceus philippinus* (Ploceidae) and the life-cycle of the Plains Cupid butterfly, *Chilades pandava* (Lycaenidae) with the red-listed *Cycas spheric* and *C. beddomei* (Cycadaceae). J Threatened Taxa 1(8): 429-433.

Ravichandran S, Kumar V, Mani K and Viswanathan K. (2007) Influence of hardness of drinking water on

egg production and egg shell thickness. Indian J Poultry Sci. 42(1): 81-83.

Reid JM, Monaghan P and Ruxton GD. (2000) Resource allocation between reproductive phases: The importance of thermal conditions in determining the cost of incubation. Proc Royal Soc B Biol Sci. 267(1438): 37-41.

Reynolds SJ, Davies CS, Elwell E, Tasker PJ, Williams A, Sadler JP and Hunt D. (2016) Does the urban gradient influence the composition and ectoparasite load of nests of an urban bird species? Avian Biol Res. 9(4): 224-234.

Roberts JR. (2004) Factors affecting egg internal quality and egg shell quality in laying hens. J Poultry Sci. 41(3): 161-177.

Romanoff AL and Romanoff AJ. (1949) The avian egg. John Wiley Sons, Inc., New York.

Scheideler SE. (1998) Eggshell calcium effects on egg quality and Ca digestibility in first-or third-cycle laying hens. J Appl Poultry Res. 7(1): 69-74.

Shanahan DF, Strohbach MW, Warren PS and Fuller RA. (2014) The challenges of urban living. In: Avian Urban Ecology, (eds.) Gil D. and Brumm H., Oxford University Press, Oxford, UK, pp. 3-20.

Shen TF and Chen WL. (2003) The role of magnesium and calcium in eggshell formation in Tsaiya ducks and Leghorn hens. Asian-Australasian J Anim Sci. 16(2): 290-296.

Sohi GK and Kler TK. (2017) Adaptations in avian nesting behavior in relation to indigenous trees and housing structures in Punjab. J Entomol Zool Stud. 5(5): 1045-1051.

Stanley TR. (2002) How many kilojoules does a Black-billed Magpie nest cost? J Field Ornithol. 73(3): 292-297.

Suárez-Rodríguez M, López-Rull I and Macías Garcia C. (2013) Incorporation of cigarette butts into nests reduces nest ectoparasite load in urban birds: new ingredients for an old recipe? Biol Lett. 9(1): 20120931.

Townsend AK and Barker CM. (2014) Plastic and the nest entanglement of urban and agricultural crows. PLoS One 9(1): e88006.

Umbraško I, Petjukevičs A, Batjuka A and Harlamova N. (2021) Evaluation of calcium carbonate content in eggshells of avian, turtle, snail, and ostrich using chemical analysis and scanning electron microscopy. In: Environment, Technologies, Resources. Proc International Scientific Practical Conference 1: 244-249.

van der Hoek Y, Gaona GV and Martin K. (2017) The diversity, distribution and conservation status of the tree-cavity-nesting birds of the world. Diversity Distributions 23(10): 1120-1131.

Votier SC, Archibald K, Morgan G and Morgan L. (2011) The use of plastic debris as nesting material by a colonial seabird and associated entanglement mortality. Mar Pollut Bull. 62(1): 168-172.

Walsh PT, Hansell M, Borello WD and Healy SD. (2010) Repeatability of nest morphology in African weaver birds. Biol Lett. 6(2): 149-151.

Wang Y, Chen S, Blair RB, Jiang P and Ding P. (2009) Nest composition adjustments by Chinese Bulbuls *Pycnonotus sinensis* in an urbanized landscape of Hangzhou (E China). Acta Ornithol. 44(2): 185-192.