The Use of Foreign Objects in Birds' Nests

Author: Rosa Korte
Student number: S4023528
E-mail address: r.j.korte@student.rug.nl
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University: University of Groningen
Supervisor: Prof. dr. S. Verhulst

Foreword

The research in this thesis focuses on the possible reasons for birds incorporating foreign objects in their nests. This thesis is written in the context of my bachelor's degree program in Biology at the University of Groningen. During my studies, I chose to specialize in Ecology and Evolution. The surrounding nature has always been source of inspiration and fascination for me. I found it intriguing to delve into the nest-building behavior of birds and explore the potential functions of foreign objects. Additionally, I found the influence of human activities and urbanization to be an intriguing aspect.
I would like to express my gratitude to Simon Verhulst for enabling me to write this thesis. I am thankful for his guidance and support as my supervisor throughout the writing process.

I hope you enjoy reading my thesis.

Rosa Korte
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Abstract

Birds nests play a critical role in parental care, providing protection for the eggs and nestlings against environmental stressors. While nest designs vary across bird species, certain common characteristics can be observed. Birds make specific material choices during nest building to optimize protection, camouflage, and, insulation. Common materials found in bird habitats, such as leaves, feathers, and twigs, are commonly incorporated into the nest. However, what has drawn the attention of researchers is the incorporation of foreign objects into birds' nests, particularly those of anthropogenic origin. In this thesis, I will explore the potential functions and underlying motives for the incorporation of foreign objects in birds' nests. Jackdaws (*Corvus monedula*) within a colony in Haren, The Netherlands, were observed to incorporate white pieces of paper in their nest. By comprehensively analyzing previous research on the incorporation of foreign objects, my aim is to delve into the potential motivations behind this behavior in Jackdaws. The findings from various research papers suggest that the incorporation of foreign objects in bird nests can serve various purposes, including functional aspects related to nest construction and visual aspects associated with signaling. The use of foreign objects in nests are not mutually exclusive, suggesting that multiple factors may be applicable. For instance, the incorporation of foreign objects in nest design may serve as a signal to potential mates or rivals, acting as decoration and an intraspecific signal. In the case of Jackdaws, the incorporation of white pieces of paper in the nest box may serve as a sexual signal. These nest decorations can serve as reliable indicators for conspecifics, providing insights into the signaler's viability, territory quality, and dominance, thereby reducing unnecessary conflicts over nesting spots. Another plausible explanation for the incorporation of white pieces of paper is that Jackdaws may use them as a replacement for natural nest materials, such as white feathers, believing that they possess similar beneficial properties to white feathers. Moreover, the white pieces of paper might be incorporated in nests of the jackdaw to reduce predation risk by camouflaging the eggs or confusing the predators. While the discussed hypotheses provide valuable insights, further research is needed to unravel the exact motivations behind this intriguing behavior. Specifically, more in-depth investigations are necessary to determine the specific role of white pieces of paper in Jackdaw nests.

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Introduction

Birds' nests are complex structures that play a vital role in avian reproduction. While nest designs vary across bird species, certain common characteristics can be observed. Nests play a critical role in parental care by protecting the eggs and nestlings from environmental stressors such as temperature fluctuations and predators (Collias, 2014; Hansell, 2000; Mainwaring et al, 2014). The protective nature of nests creates a safe environment for offspring, promoting their growth and development and ultimately enhancing breeding success (Hansell, 2000). In addition to the functional role of nests, nest construction is also influenced by sexual selection (Mainwaring et al., 2014). Depending on the species, one sex takes on the primary responsibility for nest construction, whereas in others, both sexes contribute to the building process (Hahn et al., 2021). The design of the nest can serve as a signal of quality and reproductive investment, thereby attracting potential mates (Borgia, 1985; Collias, 2014; Sergio et al., 2011). Overall, nest construction in avian species exhibits distinct preferences and architectural skills, influenced by a combination of innate behavior and knowledge acquired through previous breeding attempts. As a result, the specific type of nest constructed provides valuable insights into the interactions between birds and their environment (Collias, 2014; Hansell, 2000).

The nesting sites of bird species exhibit variations in terms of their habitat preferences and architectural skills (Collias, 2014; Hansell, 2000). Birds tend to select nest sites that minimize the risk of predation (Mainwaring et al., 2014). Many bird species nest in trees, using the branches and dense leaves of the tree to build and camouflage their nests (Hansell, 2000; Mainwaring et al., 2014). Other species prefer to nest in cavities of trees, nest boxes, and buildings (Dulisz et al., 2021; Hansell, 2000). These cavities provide safe nesting places for birds (Dulisz et al., 2021). Ground-nesting birds, on the other hand, construct their nests on exposed sites on the ground with little to no natural protection. These species rely on cryptic coloration to conceal their nests, thereby reducing visibility for both the bird and the nest to minimize predation risk (Hansell, 2000; Kull, 1977; Mainwaring et al., 2014).

Nest construction is not completely based on instinct; rather, birds incorporate learned behaviors acquired through prior reproductive experiences. In species where learning can be observed, it is predicted that experienced birds will construct nests that provide enhanced protection and increase reproductive success. Birds may collect new materials for nest construction based on their past experiences, selecting those that have found to be advantageous. A notable example is the incorporation of green plant nest materials, which can be seen as an adaptation derived from the advantages associated with using living vegetation instead of non-living materials into nest construction (Hansell, 2000; Ruiz-Castellano et al., 2018). Such innovative behavior might have spread through bird populations as an inherited trait and potentially as a learned behavior (Hansell, 2000). This adaptive construction behavior highlights the remarkable ability of birds to adjust their nest-building strategies in response to changing environmental conditions and the availability of resources in their environment (Collias, 2014; Hansell, 2000).

The nest-building behavior of birds involves many specific material choices to optimize protection, camouflage, and, insulation (Hahn et al., 2021; Hansell, 2000; Campbell et al., 2018; Bailey et al., 2015). Various materials commonly found in bird habitats, such as leaves, feathers, and twigs, are incorporated into the nest (Collias, 2014; Hansell, 2000; Mainwaring et al., 2014). However, what has drawn the attention of researchers is the incorporation of foreign objects into birds' nests. These foreign objects are frequently of anthropogenic origin, such as plastics and human-made debris, and are now commonly observed within bird nests (Hansell, 2000; Jagiello et al., 2019; Jagiello et al., 2022). The incorporation of these foreign objects in nests can serve various purposes, both functional aspects related to nest construction and visual aspects associated with signaling reproductive investment (Collias, 2014; Hahn et al., 2021; Mainwaring et al., 2014). Over the last couple of decades, there has been a notable rise in anthropogenic waste pollution, leading to alterations in bird habitats and the availability of nest construction materials

(Jagiello et al., 2019; Jagiello et al., 2022). The observed inclusion of anthropogenic materials in bird nests has raised concerns regarding potential impacts on the health and reproductive success of bird species (Jagiello et al., 2019; Jagiello et al., 2022).

The phenomenon of birds incorporating foreign objects into their nests is observed across various taxa. For instance, the Jackdaw (*Corvus monedula*), is one such species. Jackdaws are very social and are an example of a monogamous bird, wherein both the male and female actively participate in nest construction and the transportation of nesting materials to an equal extent (Hahn et al., 2021). Free-living Jackdaws within a colony at the Zoological Laboratory in Haren, The Netherlands, were observed to incorporate white pieces of paper in their nest (Figure 1). The full understanding of the consequences and motivations behind the inclusion of anthropogenic materials in birds' nests remains unclear (Jagiello et al., 2019).

In this essay, I will examine the potential reasons and ecological implications for the incorporation of foreign objects in birds nests. Through a comprehensive analysis of previous research on the incorporation of foreign objects, possibly of anthropogenic origin, in birds' nests, my aim is to delve into the potential underlying motivations behind this behavior observed in Jackdaws. The investigation will encompass exploring both functional purposes related to nest construction, as well as visual aspects associated with signaling to mates or rivals. Firstly, I will discuss the use of foreign objects and their potential functions in avian nest construction. Secondly, I will investigate the incorporation of foreign objects, particularly those originating from anthropogenic origin, and its association with the increased urbanization and human pressure on the environment. Lastly, I will describe the use of foreign objects and their potential role in reducing predation risks.

Figure 1: The nest of a Jackdaw (*Corvus monedula*). It displays the white pieces of paper incorporated inside the nest box.

Chapter 1 – The Use of Foreign Objects in Nests and Functional Hypotheses

Bird nests are intricately designed structures that facilitate successful breeding by protecting nestlings from external stressors. In order to optimize reproductive success, birds make choices regarding the incorporation of various materials during nest construction. These materials serve multiple purposes, including providing thermal insulation, enhancing the structural reinforcement of the nest and as a defense mechanism to repel parasites. Additionally, decorations in nest design can play a role in signaling (Hansell, 2000). While natural materials play a fundamental role in nest construction, recent research has delved into the behavior of birds incorporating objects of anthropogenic origin into their nests. This chapter explores the research findings and hypotheses surrounding the functional use of materials in bird nests, investigating the potential reasons and reproductive benefits behind this intriguing behavior. I will investigate the use of both natural materials and those of anthropogenic origin.

Birds select materials like feathers and fur that help regulate nest temperature. These materials can provide insulation, to ensure optimal egg incubation and nestling developmental conditions (Deeming et al., 2020; Hansell, 2000; Olborska and Kosicki, 2004). Insulating materials enables birds to create a microclimate inside the nest that is best suited to the ambient air temperature prevailing during the construction phase. Such behavior can be explained as an adaptive response, where birds incorporate specific materials in response to local temperature conditions (Campbell et al., 2018). Furthermore, natural materials like plant fibers, grasses and long animal hair are incorporated to strengthen the structure of the nest (Hansell, 2000; Olborska and Kosicki, 2004). Various bird species also incorporate anthropogenic materials such as plastic strings, foil, and fragments of clothing into their nest structures. Antczak, Hromada, Czechowski, Tabor, Zabłocki, Grzybek and Tryjanowski (2010) examined the utilization of plastic strings in nests of the Great Grey Shrike (*Lanius excubitor*), focussing on the innovative use of this new construction material. It was suggested that these human waste products have a positive influence on the strength of the nest structure (Antczak et al., 2010).

In addition to the selection of materials providing insulating benefits and enhancing structural stability, birds may also exhibit visual preferences for nest material. Kull (1977) studied color selection of nesting materials by Killdeer (*Charadrius vociferus*) and showed their preference for white-colored materials. Kull proposed that a possible function of the selection of white materials could be the increased reflectivity, aiding with thermoregulation of their open nests. This, in turn, could effectively regulate incubation temperatures contributing to a higher reproductive success (Kull, 1977; Mayer et al., 2009). Similarly, Mayer, Smith, Ford, Watterson, McCutchen, and Ryan (2009) investigated the nest construction of Piping Plovers (*Charadrius melodus*) and discovered this species to incorporate white pebbles in their nests. This selection of materials suggested the adaptation to regulate the temperature of the open nest structure in response to heat stress. Nests containing white pebbles exhibited higher heat reflection compared to nests with randomly available pebbles of different colors. This reduced the nest temperature, creating an improved microclimate for egg development. However, it should be noted that the nests containing white materials also were more contrasting in color to their surroundings, making them more visible for predators. The color selection for white materials by the Killdeer and the Piping Plovers, therefore, involves a potential trade-off between minimizing predation risk through camouflaging the nest and maximizing heat reflectance to regulate incubation temperatures. This trade-off will be further discussed in Chapter 3 (Kull, 1977; Mayer et al., 2009).

The incorporation of materials with specific colors may also play a key role in sexual signaling and attracting potential mates (Borgia, 1985; Sergio et al., 2011). Nests can be seen as an extended phenotype of the bird, expressing the quality of the individual who

constructs the nest (Järvinen and Brommer; Sergio et al., 2011). Foreign objects, which may include brightly colored anthropogenic materials, serve as decorative elements in nest design (Borgia, 1985; Sergio et al., 2011). These decorations function in this case as an intraspecific signal of quality and reproductive investment. Female bowerbirds, observed in the study of Borgia (1985) demonstrated a mating preference influenced by the nest construction of males. The best constructed and most decorated nests were favored by the female birds, increasing the likelihood of successful mating for those males (Borgia, 1985).

Decorations in nest design are not only a reliable indicator of individual quality, but also of territorial quality. The presence of these foreign objects in nests design can serve as a signal to other birds, indicating that the nesting spot is already occupied and communicating territorial boundaries. Sergio, Blas, Blanco, Tanferna, López, Lemus and Hiraldo (2011) showed that nest decorations can act as reliable indicators for conspecifics, providing insights into the signaler's viability, territory quality, and dominance (Sergio et al., 2011).

Conover (1985) showed fascination with the fact that birds not only accept foreign objects in their nests but even actively selected them, prompting an investigation into the potential benefits of this behavior. Conover (1985) proposed three hypotheses to explain the incorporation of foreign objects in nests. He suggested that birds may mistake the objects for food items or confuse them with their own eggs. In such cases, it is suggested that birds are unable to discriminate foreign objects from food items or their own eggs. Conover also proposed that egg-like objects could serve as a stimulus for incubation (Conover, 1985; Anderson & Brush, 2016). To support this, Conover referred to a study conducted by Coulter (1980), focussing on the hatching success of gulls. Coulter observed that gulls incubating three eggs had greater hatching success compared to gulls incubating smaller clutches. He hypothesized that egg-like foreign objects that were incorporated in the nest served as an important incubation stimulus in smaller clutches. (Conover, 1985; Coulter, 1980).

Lastly, the use of foreign objects in bird nest construction may serve as a defense mechanism to repel parasites. Bird species that reuse nest sites, such as nest boxes, encounter a higher exposure to parasites and pathogens. Given that fungi, viruses, and bacteria can remain dormant in nest debris and feces for an extended period, even surviving freezing temperatures, birds breeding in reused sites have an elevated risk of infection. This accumulation of high parasite loads can lead to nestling mortality (Clark and Mason, 1985). Ruiz-Castellano, Tomás, Ruiz-Rodríguez and Soler (2018) proposed that birds may prefer to incorporate natural foreign objects with anti-parasitic and antimicrobial properties in their nest. White feathers and various aromatic green plant species, were predicted to protect nestlings against pathogens due to their higher antimicrobial properties (Ruiz-Castellano et al. 2016; Ruiz-Castellano et al., 2018). Indeed, the spotless starling (*Sturnus unicolor*) preferred to select white feathers in their nest structure. Anthropogenic materials that are found to have anti-parasitic properties are cigarette butts (Suarez-Rodriguez et al., 2012; Suárez-Rodríguez et al., 2013). Suárez-Rodríguez and Macías García (2014) showed that the incorporation of cigarette buts had a beneficial effect on nestling success of House finches (*Carpodacus mexicanus*) due to its anti-parasitic properties. However, it is possible that the long-term costs of nestling survival due to the exposure to these toxins become evident over time (Suárez-Rodríguez and Macías Garcia, 2014).

Chapter 2 – The Use of Foreign Objects in Nests in Relation to Human Presence

The incorporation of foreign objects of anthropogenic origin in nest structures was hypothesized to be a response of birds to pollution of their breeding habitat (Jagiello et al., 2019). The amount of anthropogenic waste in the environment is increasing and considered to be one of the major threats to species (Jagiello et al., 2019; Jagiello et al., 2022). Approximately 37% of the total global annual waste, which amounts to around 2 billion tons, finds its way to wild-life habitats where it accumulates. And this amount is only increasing, as it is predicted to be doubled by 2050 (Jagiello et al., 2022; Kaza et al., 2018). This growing accumulation of anthropogenic waste will influence the habitat of wildlife and will have an enormous impact on all ecosystems. In this Chapter, I will delve into the research findings and hypotheses surrounding the possible influences of human-induced environmental pressure on the use of foreign objects, particularly those of anthropogenic origin, in avian nests.

In contradiction to the potential benefits discussed in Chapter 1 regarding the incorporation of anthropogenic materials in nest construction, Jagiello, Dylewski, Tobolka and Aguirre (2019) suggest that human waste products may be incorporated into bird nests simply because natural nest material is scarce or unavailable (Jagiello et al., 2019; Jagiello et al., 2022). This study analyzed the literature on the incorporation of anthropogenic materials by birds in response to pollution, establishing the first close link between human pressure and this observed behavior in bird nest construction. The incorporation of anthropogenic objects was found to be correlated with increased human pressure on the environment (Jagiello et al., 2019). As previously discussed, nest-building behavior of birds is an adaptive trait influenced by the availability of nest construction materials (Hansell, 2000; Collias, 2014). It is suggested that the availability of natural nest materials, like plants, feathers, animal hair and fur, is reduced in urban environments. Inversely, the presence of anthropogenic waste materials is positively associated with human presence (Jagiello et al., 2019; Jagiello et al., 2022). The behavior of birds to incorporate anthropogenic materials in their nests is believed to be a response to the scarcity of natural nest materials in urban environments, leading to their replacement with foreign objects of anthropogenic waste. This hypothesis is referred to as the availability hypothesis (Jagiello et al., 2019; Jagiello et al., 2022; Antczak et al., 2010; Lee et al., 2015).

The availability hypothesis is further explored by Jagiello, Corsini, Dylewski, Ibáñez-Álam, and Szulkin (2022), examining the correlation between the presence of anthropogenic waste materials in the breeding habitat and nest construction of the blue tit (*Cyanistes caaeruleus*) and the great tit (*Parus major*) and its effect on reproductive success. Once again, a positive relationship was observed between the amount of anthropogenic pollution in the environment and human presence. Moreover, a higher level of urbanization intensity and human presence was associated with a higher number of anthropogenic materials in the nests of the great tit. When the amount of debris in the nest construction was high, the natural nest materials was found to be lower in nests of the blue tit and the great tit. These findings agree with the availability hypothesis, supporting the notion of an increased incorporation of anthropogenic materials in nest construction due to human pressure.

The incorporation of anthropogenic materials in nest constructions has raised concerns about its potential impacts on bird species health and reproductive success (Hansell, 2000; Jagiello et al., 2019; Jagiello et al., 2022). The incorporation of debris in nest construction can have negative consequences on birds, such as ingestion and entanglement, which may ultimately lead to death (Antczak et al., 2010; Jagiello et al., 2019). Antczak (2019) identified entanglement in plastic strings as the primary cause of nestling mortality in Great grey shrikes (*Lanius excubitor*). Plastic strings can also pose a threat to adult birds. Furthermore, anthropogenic materials such as cigarette butts can have long-term consequences, as they expose birds to toxins (Jagiello et al., 2022; Suárez-Rodríguez and Macías Garcia, 2014).

Additionally, Jagiello, Corsini, Dylewski, Ibáñez-Álam, and Szulkin (2022) have revealed a detrimental association between the incorporation of anthropogenic nest materials and the reproductive success of blue tits (*Cyanistes caaeruleus*), highlighting a species-specific susceptibility of urban birds to pollution (Jagiello et al., 2022). Although this relationship is significant, further investigation is necessary to establish the causal relationship behind it. The nests containing higher amounts of anthropogenic materials also contained fewer natural materials, such as feathers, which are essential for thermal insulation and serve as a defense mechanism to repel parasites (Jagiello et al., 2022; Ruiz-Castellano et al. 2016; Ruiz-Castellano et al., 2018). Consequently, this may lead to negative reproductive outcomes in the blue tit population. Moreover, feathers in the blue tit nests can also be used as a signals of female quality, serving as an extended phenotype. The reduction in available feathers in bird's habitat may reduce blue tit's chances of successful mating and reproductive success. This emphasizes the anthropogenic interference driven by urban environments, affecting the extended phenotype and reproductive success of birds. Further research is needed to explore the relationship between parental quality, expressed phenotypically through the presence of anthropogenic materials in the nest, and fitness (Jagiello et al., 2022). Additionally, more research is required to determine whether the incorporation of anthropogenic materials directly causes the lower reproductive success of blue tits or if overall reproductive success is diminished in a urban environments with a higher presence of anthropogenic materials.

Chapter 3 – The use of foreign objects in nests and its role in reducing predation

Nest failure in birds is primarily attributed to predation, making it the dominant factor for reproductive success. Alterations in nest construction behaviors have been observed to change in response to variations in predation risk (Hansell, 2000; Ocampo and Londoño, 2015). Birds also actively select materials that blend with the surroundings, effectively camouflaging their nest and reducing visibility to potential predators (Bailey et al., 2015). This Chapter explores the research findings and theories of the use of foreign objects as their potential role to reduce egg visibility and predation risk.

Incorporation of foreign objects in nests may serve as a form of camouflage, helping to conceal the nest or eggs from potential predators (Hansell, 2000). The color selection of nesting materials has been observed in Killdeer birds (Kull, 1977). These birds have shown a visual preference for white-colored objects, as they are frequently incorporated into their nests structure (Kull, 1977). The possible function of this preference could be related to the reflective nature of white-colored objects, aiding in thermoregulation of the nest, as described in Chapter 1 (Kull, 1977; Mayer et al., 2009). Additionally, the reason of the selection for white materials by the Killdeer could be cryptic coloration. Cryptic coloration is a form of concealment. The white colors of the anthropogenic materials in the nest disrupts the body outlines of the bird and thereby making the bird and the nest less visible for predators (Hansell, 2000; Kull, 1977). White coloration could also mimic light reflecting off water or resemble sunlit leaves or branches, concealing the nest from potential predators (Hansell, 2000). These findings imply that the incorporation of foreign objects with specific colors can be used to camouflage the nest which will reduce the conspicuousness of the eggs within the nest.

Conversely, conspicuous colors in bird nests can be unfavorable and enlarge the risk of predation. This is thought to cause a trade-off between the selection of nest material favoring nest crypticity and materials that effectively regulate incubation temperatures (Mayer et al., 2009). Mayer, Smith, Ford, Patterson, McCutchen and Ryan (2009) examined the nest construction by Piping Plovers. They were, in addition to the Killdeer, also observed to incorporate whiter, more egg-like, pebbles in their nests which can indicate to a selection of materials that regulates the temperature of the nest and favors crypticity. Nevertheless, these nests were found to have a higher risk of predation due to the conspicuous color contrast between the nest and its surroundings. The study concluded that the color selection of pebbles suggests a trade-off between minimizing predation risk by camouflaging the nest and maximizing heat reflectance to regulate incubation (Mayer et al., 2009).

Another strategy to prevent predation is observed by some cavity-nesting bird species. When the parents leave the nest to forage, they cover the eggs with nest material like leaves, moss, and feathers (Slagsvold and Wiebe, 2021). To a potential predator inspecting the nest, the cavity might appear empty which may reduce the risk of the predator entering. Conversely, when the white eggs are exposed, they enable a predator on the hunt to easily determine that the nest is currently unoccupied. Due to the covered eggs, the cavity nest appears dark which was found to cause some hesitation by the predator (Slagsvold and Wiebe, 2021). Egg covering does not only hide the eggs for the visible eye of predators, but also improves the temperature for incubation, by providing thermal insulation. Resulting in a higher degree of egg coverage when the temperatures are colder during the egg-laying period (Collias, 2014; Loukola et al., 2020).

Discussion

In this essay I examined the various reasons why birds incorporate foreign objects into their nests. Many examples were being mentioned, and when we look at all the findings from the research papers displayed in this essay, it becomes clear that the incorporation of foreign objects in bird nests can have both positive and negative consequences on bird species reproductive success. Here, I will discuss the potential underlying motives, encompassing both functional and visual reasons for the behavior of incorporation of white papers in the nest, as observed by Jackdaws (Figure 1).

In Chapter 1, we investigated various functional hypotheses regarding the incorporation of foreign objects in avian nest construction. The materials selected by birds serve diverse purposes, such as reinforcing the nest's structure and providing thermal insulation. These functions ultimately benefit the nest, eggs, and, eventually, the nestlings (Bailey et al., 2015; Campbell et al., 2018; Hansell, 2000). Natural materials like plants, grasses and animal hairs enhance the stability of the nest structure (Hansell, 2000; Olborska and Kosicki, 2004). Additionally, foreign objects such as plastic strings and synthetic fibers may play a crucial role in reinforcing the nest construction in modern times (Antczak et al., 2010). However, since Jackdaws nest in nest boxes, the use of foreign objects that positively affect the nest strength may not be essential. Breeding in a nest box provides a safe and secure space for birds to breed, eliminating the risk of nest failure due to a fragile nest construction. Nesting materials also play a vital role in providing insulation, ensuring optimal temperatures for successful egg incubation and nestling development. Nevertheless, Figure 1 indicates that the white pieces of paper are not incorporated into the nest structure itself but rather placed around it inside the nest box. Consequently, the presence of these white pieces of paper observed in the Jackdaw nests may not be attributed to their role in insulation or nest structure.

We also discussed the potential of white colored objects aiding in nest thermoregulation. This was was observed in the cases of the Killdeer and Piping Plovers, wherein they incorporated white-colored materials into their nest to regulate nest temperature in response to heat stress (Mayer et al., 2009; Kull, 1977). However, it is important to note that this thermoregulation mechanism requires direct sunlight and thus will be primarily relevant to open nests. In contrast, external radiation reaching nests inside nest boxes is limited. As a result, we can reject the hypothesis that the white pieces of paper found in Jackdaw nests function to regulate nest temperature by reflecting sunlight.

Furthermore, the incorporation of foreign objects with specific colors in nest design may serve as a signal to potential mates or rivals. These foreign objects could play a role in nest building as decoration, serving as intraspecific signal between male and female birds. The presence of such decorations indicate a high-quality individual that has build the nest and shows investment in reproduction. This can potentially increase the chances for successful mating (Borgia, 1985; Sergio et al., 2011). In the case of Jackdaws, as a monogamous bird species with both males and females contributing equally to nest building for reproduction (Hahn et al., 2021), the incorporation of white pieces of paper in the nest box may serve as a sexual signal. However, this signal may not be aimed to attract a mate, as Jackdaws are typically already mated long before the nest construction period. Therefore the use of white pieces of paper as an intraspecific signal to enhance mating success may not be a plausible functional reason for the observed behavior in Jackdaws. Unfortunately, it is still unknown during which stage of nest building the birds incorporate these papers. Further research is required to better understand if these foreign objects indeed play a role in sexual signaling.

Foreign objects in nest design may also serve as a signal to indicate that the nesting spot is occupied and to establish territorial boundaries (Sergio et al., 2011; Hansell, 2000). Nest decorations can act as reliable indicators for conspecifics, providing valuable insights into the signaler's viability, territory quality, and dominance (Sergio et al., 2011). I believe this could be another plausible hypothesis for the use of white pieces of paper in Jackdaw

nests. Considering the monogamous and social nature of Jackdaws and their cooperative nest building behavior, white pieces of paper could be used as an intraspecific signal to reduce unnecessary conflicts between individuals concurring for the same nesting spot, thereby maintaining social cohesion. However, once again, to explore this potential function further research is warranted regarding the timing and method of the incorporation of the white papers to gain a deeper understanding of the implications in their social dynamics.

In the final paragraph of Chapter 1, I explored the potential anti-parasitic and antimicrobial properties of foreign objects in bird nests. Certain aromatic green plant species and white feathers were found to possess higher antimicrobial properties, providing protection to nestlings (Ruiz-Castellano et al., 2018). As nest boxes are often reused as nest sites each year, there is an increased risk of high parasite loads that can lead to nestling mortality (Clark and Mason, 1985). The incorporation of foreign objects with parasite-repellent properties could potentially enhance the reproductive success of Jackdaws. While no study has explicitly claimed that white papers contained these properties, the active selection and incorporation of materials with chemical compounds or antimicrobial properties suggest that birds have the ability to recognize and utilize these objects for their potential benefits in protecting their offspring. Considering the availability hypothesis discussed in Chapter 2, suggesting that the behavior of birds of incorporating anthropogenic materials in their nests is a response to the scarcity of natural nest materials in urban environments (Jagiello et al., 2019; Jagiello et al., 2022; Antczak et al., 2010; Lee et al., 2015), it is plausible that jackdaws incorporate white pieces of paper as a replacement for natural nest materials, such as white feathers. The white pieces of paper might be mistaken for or possibly incorporated by Jackdaws due to the belief that they possess similar beneficial properties to white feathers. This hypothesis of the adaptation to the availability of materials in urban environments could further contribute to the understanding of the observed behavior in the Jackdaw. Further research is needed to explore if white papers could indeed have antimicrobial properties.

Lastly, I examined the use of foreign objects and their potential role in reducing predation in Chapter 3. Predation is a primary cause of nest failure in bird species, highlighting the importance of effective camouflage and protection of the nest and nestlings (Ocampo and Londoño, 2015; Hansell, 2000). Conspicuous colors in bird nests can increase the risk of predation. However, foreign objects with specific colors may serve to camouflage and conceal the eggs, rendering them less visible for predators or causing confusion. White-colored objects might help to conceal eggs from predators, thereby enhancing reproductive success (Mayer et al., 2009; Kull, 1977). The white coloration could also mimic light reflection of water or resemble sunlit leaves or branches, effectively hiding the nest from potential predators by blending into the background (Hansell, 2000). By incorporating white papers into the nest, a predator may not recognize it as a potential target or mistake it for an empty surroundings, such as sunlit leaves. Additionally, the presence of numerous white objects in the nest box may confuse the predator, making it difficult to spot the real eggs in a blink of an eye. This may enlarge the challenge of taking the actual egg for the predator. These findings suggest that incorporating foreign objects with specific colors can be used by the Jackdaw to enhance the likelihood of reproductive success by reducing the risk of predation. It is important to mention that the effectiveness of foreign objects in reducing egg visibility or confusing predators may vary depending on the predator species, environmental conditions, and specific nest box designs. Predators who can see very clearly or those who are familiar with the nest boxes may still be able to detect the eggs despite the presence of disruptive, white colored objects. Additionally, the availability and accessibility of suitable foreign objects may also influence the extent to which birds can use this strategy.

In conclusion, the discussed findings shed light on the potential benefits of the white pieces of paper in enhancing the reproductive success of Jackdaws. The various proposed hypotheses for the use of foreign objects in nests are not mutually exclusive, suggesting that multiple factors may be applicable. Further research is necessary to unravel the exact underlying motivations behind this intriguing behavior. Specifically, more in-depth investigations are needed to determine the specific role of white pieces of paper in the nests

of Jackdaws. By unraveling the underlying motives, we can gain valuable insights into our understanding of avian behavior in nest construction.

Afterword

It was an exiting and educational experience for me to write this thesis. I am pleased with the final outcome. I thoroughly enjoyed reading scientific papers on the nest construction behavior of birds and their incorporation of foreign objects. Especially the objects and materials of anthropogenic origin and its effect on species health. Initially, I found it challenging to establish a good starting point of my writing due to the large amount of information and various hypotheses. However, I am delighted that I managed to overcome this obstacle and complete the thesis.

Rosa Korte

References

Anderson, A., & Brush, J. (2016). Observation of american oystercatchers (haematopus palliatus) incubating a foreign object. The Wilson Journal of Ornithology, 128(4), 939–941. https://doi.org/10.1676/15-190.1

Antczak, M., Hromada, M., Czechowski, P., Tabor, J., Zabłocki, P., Grzybek, J., & Tryjanowski, P. (2010). A new material for old solutions—the case of plastic string used in Great Grey Shrike nests. *Acta ethologica*, *13*, 87-91.

Bailey, I. E., Muth, F., Morgan, K., Meddle, S. L., & Healy, S. D. (2015). Birds build camouflaged nests. The Auk: Ornithological Advances, 132(1), 11e15. https:// doi.org/ 10.1642/auk-14-77.1

Borgia, G. (1985). Bower quality, number of decorations and mating success of male satin bowerbirds (Ptilonorhynchus violaceus): an experimental analysis. *Animal Behaviour*, *33*(1), 266-271.

Campbell, B. L., Hurley, L. L., & Griffith, S. C. (2018). Behavioural plasticity under a changing climate; how an experimental local climate affects the nest con- struction of the zebra finch Taeniopygia guttata. Journal of Avian Biology, 49(4), 1e8. https://doi.org/10.1111/jav.01717

Clark, L., & Mason, J. R. (1985). Use of nest material as insecticidal and anti-pathogenic agents by the european starling. Oecologia, 67(2), 169–176. https://doi.org/10.1007/ BF00384280

Collias, N. E., & Collias, E. C. (2014). *Nest building and bird behavior* (Vol. 857). Princeton University Press.

Conover, M. R. (1985). Foreign objects in bird nests. The Auk, 102(4), 696–700.

Coulter, M. C. 1980. Stones: an important stimulus for gulls and terns. Auk 97: 898-899.

Deeming, D. C., Griffiths, J. D., & Biddle, L. E. (2020). Material type and position determines the insulative properties of simulated nest walls. *Ardeola*, *67*(1), 127-136.

Dulisz, B., Stawicka, A. M., Knozowski, P., Diserens, T. A., & Nowakowski, J. J. (2021). Effectiveness of using nest boxes as a form of bird protection after building modernization. Biodiversity and Conservation, 31(1), 277–294. https://doi.org/10.1007/s10531-021-02334-0

Hahn, L. G., Hooper, R., McIvor, G. E., & Thornton, A. (2021). Cooperative nest building in wild jackdaw pairs. Animal Behaviour, 178, 149–163. https://doi.org/10.1016/ j.anbehav.2021.06.004

Hansell, M. H. (2000). Bird nests and construction behaviour. Cambridge University Press.

Jagiello, Z., Corsini, M., Dylewski, Ł., Ibáñez-Álamo, J. D., & Szulkin, M. (2022). The extended avian urban phenotype: anthropogenic solid waste pollution, nest design, and fitness. The Science of the Total Environment, 838(Pt 2), 156034–156034. https://doi.org/ 10.1016/j.scitotenv.2022.156034

Jagiello, Z., Dylewski, Ł., Tobolka, M., & Aguirre, J. I. (2019). Life in a polluted world: a global review of anthropogenic materials in bird nests. Environmental Pollution, 251, 717–722. https://doi.org/10.1016/j.envpol.2019.05.028

Järvinen, P., Brommer, J.E., 2020. Lining the nest with more feathers increases offspring recruitment probability: selection on an extended phenotype in the blue tit. Ecol.Evol. (September), 1–7 https://doi.org/10.1002/ece3.6931.

Kaza, S., Yao, L.C., Bhada-Tata, P., Van Woerden, F., 2018. What a Waste 2.0: A Global Snap- shot of Solid Waste Management to 2050. Urban Development. World Bank, Washington, DC.

Lee, K., Jang, Y.C., Hong, S., Lee, J., Kwon, I.K., 2015. Plastic marine debris used as nesting materials of the endangered species Black-faced Spoonbill Platalea minor decreases by conservation activities. J.Korean Soc.Mar.Environ.Energy 18 (1), 45–49. https://doi. org/10.7846/JKOSMEE.2015.18.1.45.

Loukola, O. J., Adamik, P., Adriaensen, F., Barba, E., Doligez, B., Flensted-Jensen, E., ... & Forsman, J. T. (2020). The roles of temperature, nest predators and information parasites for geographical variation in egg covering behaviour of tits (Paridae). *Journal of Biogeography*, *47*(7), 1482-1493.

Mainwaring, M. C., Hartley, I. R., Lambrechts, M. M., & Deeming, D. C. (2014). The design and function of birds' nests. Ecology and Evolution, 4(20), 3909–3928. https://doi.org/10.1002/ece3.1054

Mayer, P. M., Smith, L. M., Ford, R. G., Watterson, D. C., McCutchen, M. D., & Ryan, M. R. (2009). Nest construction by a ground-nesting bird represents a potential trade-off between egg crypticity and thermoregulation. *Oecologia*, *159*(4), 893–901. https://doi.org/10.1007/s00442-008-1266-9

Ocampo, D., & Londoño, G. A. (2015). Tropical montane birds have increased nesting success on small river islands. The Auk, 132(1), 1–10. https://doi.org/10.1642/AUK-14-71.1

Olborska, P., & Kosicki, J. Z. (2004). Breeding biology of the Great Grey Shrike(Lanius excubitor): an analysis of nest record cards. *Biological Letters*, *41*(2), 147-154.

Kull, R. C., Jr. (1977). Color Selection of Nesting Material by Killdeer. The Auk, 94(3), 602–604. http://www.jstor.org/stable/4085239

Ruiz-Castellano, C., Tomás, G., Ruiz-Rodríguez, M., Martín-Gálvez, D., & Soler, J. J. (2016). Nest material shapes eggs bacterial environment. *PLoS One*, *11*(2), e0148894.

Ruiz-Castellano, C., Tomás Gustavo, Ruiz-Rodríguez Magdalena, Soler, J. J., & Taborsky, M. (2018). Nest material preferences by spotless starlings. Behavioral Ecology, 29(1), 137–144. https://doi.org/10.1093/beheco/arx139

Sergio, F., Blas, J., Blanco, G., Tanferna, A., López, L., Lemus, J.A., Hiraldo, F., 2011. Raptor nest decorations are a reliable threat against conspecifics. Science (New York, N.Y.) 331 (2011), 327–330. https://doi.org/10.1126/science.1199422.

Slagsvold, T., Wiebe, K.L. Egg covering in cavity nesting birds may prevent nest usurpation by other species. Behav Ecol Sociobiol 75, 116 (2021). https://doi.org/10.1007/s00265-021-03045-w

Suárez-Rodríguez, M., López-Rull, I., & Garcia, C. M. (2012). Incorporation of cigarette butts into nests reduces nest.

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

Suárez-Rodríguez, M., Macías Garcia, C., 2014. There is no such a thing as a free cigarette; lin- ing nests with discarded butts brings short-term benefits, but causes toxic damage. J. Evol. Biol. 27 (12), 2719–2726. https://doi.org/10.1111/jeb.12531.