WHY DO SOME SHEARWATERS ACCUMULATE STONES AT THEIR NEST ENTRANCES?

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ABSTRACT

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Nest construction is a widespread form of animal architecture with adaptive functions, including offspring protection, microclimate regulation, and parasite reduction. Nests are therefore considered extended phenotype signals that reflect the behavioural, cognitive, and energetic investment of their builders. Most petrels (order Procellariiformes) breed in simple cavities, including burrows they excavate. One species, Cory's Shearwater *Calonectris borealis*, often accumulates stones at nest entrances, a behaviour rarely reported among petrels and whose function remains poorly understood. These stone accumulations are associated with increased hatching and breeding success, although the underlying mechanisms are unknown. A small, manipulative experiment revealed that adults actively relocate stones, particularly early in the breeding season. We propose that stone piles may constitute an extended phenotypic trait linked to reproductive investment, nest defence, or environmental regulation. We highlight the complexity of this behaviour and emphasize the need for further research to understand its ecological and reproductive significance.

Key words: extended phenotype, courtship, decoration, nest architecture, nesting, pebble, seabird

INTRODUCTION

Among both invertebrates and vertebrates, the construction of nests is one of the most remarkable and varied forms of animal architecture. In addition to providing a physical space for laying eggs and rearing offspring, nests fulfil multiple adaptive functions related to predator avoidance, microclimate regulation, and parasite reduction (Mainwaring et al., 2014). In recent years, it has become increasingly clear that nests can also be understood as expressions of the extended phenotype (Dawkins, 1982; Guillette & Healy, 2015). In this way, nests reflect the motor and cognitive abilities of their builders but also the energetic costs of their construction (Moreno, 2012; Schaedelin & Taborsky, 2009; Sergio et al., 2011).

Not all species rely on elaborate nest structures as part of their reproductive strategy. Most species of the seabird families Oceanitidae, Hydrobatidae, and Procellariidae (hereafter, 'petrels') nest in cavities with little ornamental or lining material. In many species, individuals excavate these burrows. However, ornithologists have noted stone accumulations at the nest entrances of Cory's Shearwater *Calonectris borealis* for a long time (Cachia-Zammit & Borg, 1987; Lockley, 1942; Roux & Jouanin, 1968). In this species, 39% and 59% of nests on Vila Islet in the Azores and Tenerife in the Canary Islands, respectively, contained stone accumulations (Ramos et al., 1997; Rodríguez et al., 2022). Moreover, stone accumulations are typically found at the entrance to nest cavities, sometimes metres away from the nest chamber (Fig. 1), an observation that contradicts the explanation by the pioneering researcher R. M. Lockley that Cory's Shearwaters accumulate stones to prevent eggs from rolling away (Cachia-Zammit & Borg, 1987; Lockley, 1942). The presence of stone accumulations in nests has been associated with higher hatching rates and breeding success, although the underlying mechanisms are unknown (Ramos et al., 1997; Rodríguez et al., 2022). Stone accumulations are rarely reported in petrels. In a non-exhaustive search of petrel literature, we found evidence of stone accumulation in fewer than 10 of 147 petrel species (mainly fulmarines; sources consulted: Billerman et al., 2020; Brooke, 2004; Cramp & Simmons, 1977; Warham, 1990).

Stone accumulations might function as an extended phenotypic signal of future reproductive investment. In avian species, such as the Black Wheatear *Oenanthe leucura*, the accumulation of stones is interpreted as an indicator of the individual's physiological and motivational state and may influence mate choice (Moreno et al., 1994; Soler et al., 1996). A similar pattern has been reported in penguins of the genus *Pygoscelis* (Fargallo et al., 2001; Morandini et al., 2021). However, this explanation is not fully satisfactory in the case of Cory's Shearwater. The high mate and nest-site fidelity of this species across successive breeding attempts (Mougin et al., 1987; Mougin, 2002) could reduce the value of this behaviour as a signal in the context of sexual selection. Furthermore, stones are left at the nest entrance from one nesting season to the next, which limits signalling capacity. Large accumulations of stones may signal social dominance over time and deter intruders, either through the presence of the accumulated stones themselves or because they help maintain white faecal deposits that may indicate occupancy (Penteriani & Delgado, 2008).

The stones may also have been deposited by successive chicks raised in the nest burrow over several years, as petrels lay only one egg per breeding attempt (Rodríguez et al., 2022). But what purpose



Fig. 1. Three examples of Cory's Shearwater *Calonectris borealis* nests on Tenerife, Canary Islands, Spain, showing the absence (top left) and presence of stone accumulations at the entrances (bottom left and right). The inset on the right shows an incubating adult. Photos were taken in Guía de Isora, Punta del Hidalgo, and Buenavista del Norte, Tenerife, on 29 July 2017, 25 June 2018, and 24 June 2017, respectively (top left, bottom left, and right). Photo credits: Beneharo Rodríguez

does this serve? One possibility is play, similar to the drop-catch behaviour observed in gulls (Gamble & Cristol, 2002). However, this explanation seems unlikely given that stone-moving is most intense before hatching (see our preliminary experimental findings below).

The accumulation of stones could serve to protect nests from predators or adverse environmental conditions. Stone mounds could reduce the size of nest entrances, making them less detectable to predators. Consistent with this hypothesis, stone accumulations at the entrance of Blackstart *Oenanthe melanura* nests have been proposed as a warning mechanism that prevents predation inside nest cavities (Leader & Yom-Tov, 1998), and Cory's Shearwater nests are at greater risk of predation when cavities have more exposed entrances (Hervías et al., 2013; Lamelas-Lopez et al., 2023). Reducing entrance size could also improve males' ability to defend burrows against nest competitors (Ramos et al., 1997). However, contrary to our expectations, we found a positive relationship between the width of nest entrances and both the presence of stones and the surface area covered by stones in nests on Tenerife (Appendix, Fig. A1, available on the website). This positive relationship may reflect the low success of breeders in attempting to close the wide entrances to their nests. This question can only be addressed through future experimental studies.

Narrower entrances could also improve the climatic and environmental conditions within the nest by promoting a more stable underground nesting environment (Ramos et al., 1997). Nest material, including its placement, can play an important role in creating a suitable microclimate (Hansell, 2000). Therefore, partially closed nest entrances would provide more insulation, resulting in more stable temperature, humidity, and light levels. In this regard, the reproductive success of Yelkouan Shearwater *Puffinus yelkouan* increases in deeper galleries, presumably due to increased insulation and better thermoregulation (Bourgeois & Vidal, 2007).

Stone accumulations could also function as doormats, enhancing nest cleanliness and potentially restricting parasite entry into nest chambers. Stones could help individuals remove dirt and prevent the plumage of fledglings and adults from coming into contact with bare ground when chicks repeatedly emerge from the nest to exercise their wings prior to fledging (Yoda et al., 2017), or when the holding pair defend the nest entrance. Contact with dusty ground

could impair plumage waterproofing, which is critical during the first days of petrels' lives at sea (Weimerskirch et al., 2019).

METHODS

To shed light on this behaviour, we conducted a manipulative study from November 2024 to November 2025 on six nests at two nesting colonies in Tenerife, Canary Islands. Three nests had already accumulated stones at the entrance, whereas the remaining three had not. In the nests with existing stone accumulations, we measured and weighed 500 stones per nest that were larger than 25 mm (maximum length measured to the nearest millimetre and weighed to the nearest gram; mean ± standard deviation [SD]: 39.2 ± 13.3 mm and 21.5 ± 27.0 g, respectively; Fig. 2). In nests without stones, we experimentally added 300 stones with similar dimensions and weights to those available in nests containing stones (43.2 ± 13.6 mm and 34.1 ± 30.6 g, respectively; Fig. 2).

To assess if birds manipulated and redistributed stones, in November 2024 (after breeding), we arranged the stones into two distinct piles consisting of large and small stones, respectively, on opposite sides of the entrance of each of the six nest cavities. We visited

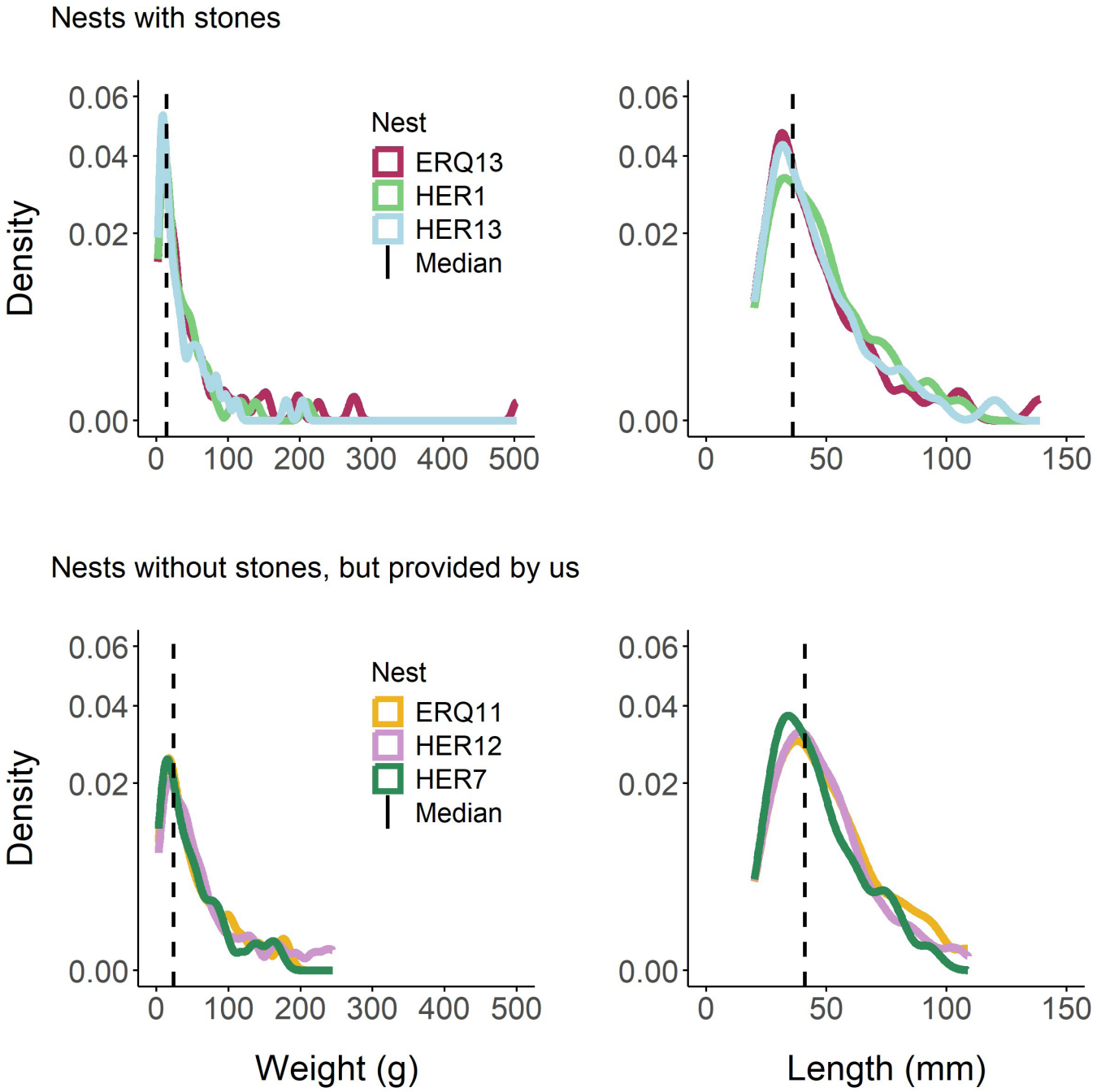

Fig. 2. Characterization of stones in Cory's Shearwater *Calonectris borealis* nests on Tenerife, Canary Islands, Spain. Density plots show the weight and length of stones in nests with pre-existing stone accumulations and in nests without pre-existing stones but in which stones were experimentally provided. The vertical dashed line indicates the median.

the nests in early April 2025, when all breeders had arrived and approximately two months before the first egg laying; in June 2025, after egg laying; and in November 2025, after breeding, to photograph the nest entrances. Camera traps (Ereagle A10, Shenzhen, China) were installed from early April to late May to record videos and photographs of the individuals.

RESULTS

The manipulative procedure did not have a catastrophic impact on the breeding success of the nests, which was similar to that observed in previous years (Appendix, Fig. A2). Camera traps showed that adult shearwaters actively manipulate stones, dragging their beaks along the ground in an attempt to locate stones in the darkness. Most petrels, including Cory's Shearwater, visit their colonies only at night (Fig. 3), making it challenging for adults to locate stones that were in close proximity to them (Appendix, Videos A1, A2). Adults repeatedly moved stones within the area surrounding the nest entrance, displacing them less than 1 m (Appendix, Videos A3, A4). Pairs of nests with pre-existing stone accumulations actively incorporated the experimentally-placed stones from both piles, whereas pairs at nests without stones at the beginning of the experiment (November 2024) rarely manipulated the piles (Appendix, Fig. A3). By June, the piles had already been reconstructed. By November, the piles remained largely unchanged, suggesting limited stone movement after the early breeding season, likely attributable to incidental rather than deliberate movements (Appendix, Fig. A3).

CONCLUSIONS

Our research shows that some adults are more likely to build stone accumulations than others, regardless of stone availability, and that stone-moving activity occurs primarily early in the breeding season. Phenotypic variation in the presence or absence of stones, and in the area covered by stones, should be studied across colonies, age groups, and individuals, as well as within individuals across breeding attempts. Furthermore, the relative contributions of males and females remains unresolved, as do the environmental and social factors that may modulate this behaviour. Further studies integrating continuous camera-trap monitoring with experimental and descriptive analyses based on larger samples are needed to understand the function and significance of stone accumulation in relation to reproductive biology.



Fig. 3. Frame from Video A1 (Appendix) showing a Cory's Shearwater *Calonectris borealis* moving a stone in the proximity of its nest entrance. The video was recorded by a camera trap in Tenerife, Canary Islands, Spain, on 12 May 2025, at 06h13:09. The video shows the bird manipulating and relocating a stone with its beak.

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ETHICS

Cabildo Insular de Tenerife (local government) issued permits to study and modify nests (expte: aff 260/22).

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AUTHOR CONTRIBUTIONS

Conceptualization: BR, AR. Formal analysis: CdT, BR, AR. Funding acquisition: AR. Investigation: CdT, BR, AR. Methodology: BR, AR. Project administration: BR, AR. Writing—original draft: CdT. Writing—review & editing: CdT, BR, AR.

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