VOCALISATION BEHAVIOURS OF MANX SHEARWATERS ON LUNDY

By

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ABSTRACT

Manx Shearwater is the most numerous breeding bird species on Lundy, and vocalisations play an important role in their communication. Here, we present an overview of knowledge on Manx Shearwater vocalisations, and of research that has been carried out on this topic on Lundy. Then observations of a previously unknown vocalisation behaviour are described, which led us to hypothesize that the nest burrows of Manx Shearwater's could amplify the calls emitted inside the burrow. Our study is the first to test this novel hypothesis. Our research on the Lundy Manx Shearwater population is a significant contribution to the study of their natural history and communication behaviour.

Keywords: *Manx Shearwater, vocalisation, communication, individuality*

INTRODUCTION

Background

A survey in 2023 conducted by The Royal Society for the Protection of Birds (RSPB) found that more than 25,000 Manx Shearwaters (*Puffinus puffinus*) bred on Lundy in that year (Davis and Jones, 2024). This was a new record for the island and the population continues to expand rapidly, a result of the successful conservation project in 2004 which removed rats from the island (Davis and Jones, 2024). Manx Shearwaters are pelagic and migratory seabirds of the family Procellariidae. These long-lived birds undertake trans-equatorial, trans-Atlantic migration every year between their oceanic breeding grounds in the North Atlantic (including Lundy) and their non-breeding areas, which extend to the seas far off the eastern South American coast (Guilford *et al*, 2009). Manx Shearwaters are long-lived, socially monogamous and reunite with the same mate year after year at their breeding colony (Brooke, 1977, Brooke, 1978). While some shearwater species do copulate extra-pair (Bried *et al*. 2010), no such study has been done in Manx Shearwater. To breed, Manx Shearwaters typically return to the same nesting burrow year after year, however, they may move burrows after a poor previous breeding outcome (Brooke, 1990). The birds form large breeding colonies on the slopes of islands in the North Atlantic.

Generally, Manx Shearwaters breed in burrows in the ground, in cave-like rocky outcrops, or even in man-made structures. On Lundy, most birds breed in old rabbit burrows, with a few pairs every year breeding in artificial burrow boxes that are accessible for research purposes (Plate 1 and more information below). The occupied burrows can be grouped into loose colonies. Generally, burrow quality is known to be associated with variation in breeding success (Thompson, 1987, Storey and Lien, 1985). In breeding locations where no pre-existing burrows are available, birds excavate new ones – construction of such can take a whole breeding season. Given the high availability of rabbit burrows, such is unlikely on Lundy. However even here, Manx Shearwater renovate their burrows every year, clean them from debris and re-excavate where needed (Lockley, 1942).

Then, Manx Shearwaters typically spend up to six weeks on the breeding grounds before egg laying, during which females spend a lot of time out on sea to gather nutrients and form the egg. On land they are active almost exclusively at night. They assemble at sea in the late afternoon in large rafts and only fly into their breeding colonies after dark (Brooke, 1990). The female typically lays one egg per breeding season (Harris, 1966), on Lundy starting in May. The chicks hatch in June and July (Brooke 2004), and both parents provide parental care to the nestling over a period of approximately 62 days (Brooke, 1990).

How Manx Shearwaters initially manage to find their mate after such long-distance migration, and how they recognise each other among thousands of conspecifics present at the colony, has drawn the interest of researchers. The answer to both questions may lie in the shearwaters' vocalizations. Given that their eyes are not specifically adapted to night vision (Martin and Brooke, 1991), it is unlikely that they rely purely on vision to recognise and locate their mate and nest burrows in the dark. However, upon arriving at the colony, both sexes emit a series of prolonged rasping calls, in the air or from the ground. This behaviour implies that vocalisation may be important for recognising and locating their mate (Brooke, 1990).

Nest Burrow Inspection Behaviour

In 2021, we noted a previously undescribed behaviour in Manx Shearwater. We used motion-activated infra-red trail cameras to passively record Manx Shearwaters on the breeding site on Lundy. The cameras were set pointing towards the entrance of natural burrows, so that every time when a bird entered or left the burrow the camera would record its movements and sound. We found a Manx Shearwater of unknown sex approaching a burrow, then stuck its head into the entrance, called into the burrow, and then left without entering (Sun *et al*, 2022). This behaviour had not been previously described and led to the novel hypothesis that Manx Shearwaters may use vocalisations in the context of burrow assessment during prospecting for nesting sites.

Manx Shearwater vocalisations differ between islands, colonies and individuals

To be used as cues for mate recognition, vocalisations must vary between individuals and contain information about individual identity. This individually distinct information coded in vocalisations, or "individual vocal signature", has been found in many bird and mammal species (Beecher, 1989; Seyfarth and Cheney, 2014; Thiebault *et al*. 2016). Earlier studies suggested that dialects existing among Manx Shearwaters on different islands (James, 1985).

The recordings of Manx Shearwaters on Lundy were included to test this hypothesis, revealing the existence of call variations among colonies (Du, 2023). This was confirmed in a follow-up study using data from the Lundy colonies and from three further colonies on Bardsey, which also found evidence for dialects among islands (Zhang, 2024).

It is long known that Manx Shearwaters females respond to their mate's call exclusively, while males were equally likely to respond to any female calls (Brooke, 1978). These behaviours suggest that at least male calls can contain elements that identify them to the females – individual signatures. We suggest that these signatures can account for the individual recognition in Manx Shearwaters. We conducted a quantitative analysis to confirm the existence of individual vocal signatures on the Lundy birds. Using acoustic analytic methods, we found that calls of Manx Shearwaters indeed contained individual signatures and identified temporal features (such as durations and intervals) and low-frequency components are most important for encoding individual signatures (Sun *et al*. 2023).

Here, we present a follow-on study testing whether Manx Shearwater burrow shapes change the sound of vocalisations. To be used for localisation, the vocalisations are required to propagate efficiently. Manx Shearwaters make calls from inside the burrow, and these calls will be louder for recipients present directly in the direction that the burrow tunnel points at than for recipients in other directions (Storey 1984). If this were true, burrow shape might be an adaptive trait that birds flying past can use to locate individuals in burrows. However, to what extent the burrows do amplify the calls produced from inside remains to be tested. Therefore, we designed and performed experiments to test the amplification effect of Manx Shearwater breeding burrows.

METHODS

Study site

The study site is a grassy slope on the west coast of Lundy, between Old Light and Battery Point, where the breeding density is highest among accessible colonies (Booker and Price, 2014). Apart from natural Manx Shearwater burrows, 10 artificial nest boxes were set on the study site by the RSPB in 2016 to study the breeding biology of Manx Shearwaters. These artificial burrows are wooden boxes of the same size, half-buried in the earth, connected to the ground with a plastic tube to be the entrance. Plate 1 shows a chick in such a box.

Measuring the amplification effect of the burrows

The burrows' quality for amplifying the bird calls was tested using playback experiments. In brief, a playback of two Manx Shearwater calls was played inside the burrows and re-recorded from outside the burrows at a 1 m distance. Using the same set-up, the same playback was played outside the burrows and re-recorded at 1 m from playback location, in the close vicinity of the burrow. By comparing the continuous sound level (Leq) of the two recordings, we quantified the burrows' ability to amplify sound played inside to the outside. We ran this experiment for 31 natural burrows and the 10 artificial nest boxes within the study area. Experiments were performed during the daytime in calm weather (wind speed < 8 mph, no rain) in the pre-breeding season (16 – 21 April 2021), when most of the burrows were not occupied by birds, to prevent disturbance. The recordings were then calibrated and used for acoustic analysis.

Plate 1: Manx Shearwater chick in a nest box on Lundy West Side 11.07.2020 © Dean Jones.

Acoustic analysis

The amplification effect of the burrows was analysed in Raven Pro 1.6 (Cornell Laboratory of Ornithology). Because the playbacks played inside the burrows were further from the microphone than those played at the opening of the burrows, we expected the former to be quieter than the latter due to attenuation of sound pressure with distance, if there was no burrow amplification effect. This loss of Leq caused by distance was corrected using the spherical spreading loss equation: $Leq_2 = Leq_1 + 20*\log_{10}(d_1/d_2)$, where Leq_2 is the Leq corrected to the amplitude at 1 m, Leq1 is the measured Leq at distance d_1, and d_1/d_2 is the ratio of the distances from the sound source to microphone.

Statistical analysis

Statistical analysis was performed in R 4.0.3 (R Core Team, 2020). We compared the corrected Leq of calls played at the entrance of the burrows with the Leq of calls played inside of the burrows using a Gaussian linear mixed effects model (LMM), with corrected Leq as the response variable, position and call as fixed factors, and burrow as a random factor.

RESULTS

We found that for natural burrows, the Leq of calls played from inside a burrow was higher than the ones played outside the entrance of the burrow, even after correcting for distance ($n = 31$. LMM: $r = 0.800$, $p = 0.03$). However, this amplification does not compensate for the energy loss caused by distance (1.58 dB loss of Leq). In other words, for a recipient standing at 1 m from the entrance of the burrow, a bird calling from inside the burrow still sounds quieter than a bird calling at the entrance of the burrow. The amplification effect was significantly higher in the artificial burrows, not only compensating for the energy loss due to distance but even increasing the amplitude of calls from inside by 4.52 dB, such that calls from inside were even louder than calls at the entrance, despite the further distance the sound had to travel ($n = 10$. LMM: $r = 4.518$, $p < 0.001$, Figure 1).

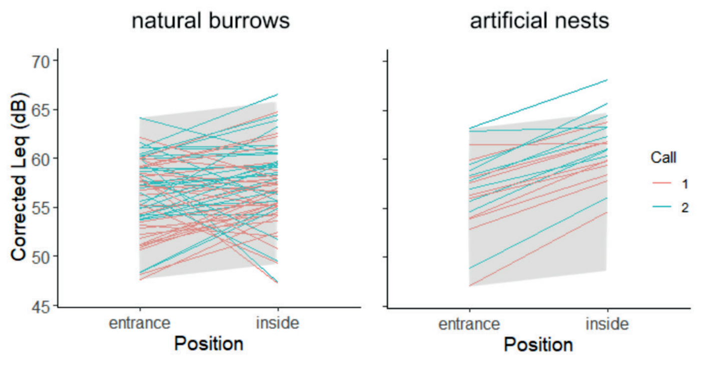

Figure 1. Continuous sound level received in 1m distance from either emission of vocalization inside a Manx Shearwater burrow on Lundy, or from outside the entrance (in dB). Lines depict differences in Leq (equivalent continuous sound level) in dB, corrected for distance. Red lines indicate the first call in the playback file and blue the second call. The two playback calls differed in amplitude and spectral properties and so were treated separately in the analysis. The shading indicates how much amplification an inside call needs to compensate the attenuation caused by distance. Both natural burrows and artificial nests amplify the calls ($p = 0.03$ and < 0.001 respectively), but in natural burrows, the amplification does not compensate the attenuation caused by distance ($r = 0.800 < 1.58$).

DISCUSSION

We found the natural nest burrows amplified calls produced inside the burrows, but this amplification effect was too weak to compensate for the loss caused by distance, if the receiver remained in the same place. In contrast, artificial nest boxes did amplify the calls, potentially due to the resonance of the construction. We found a large variation in the amplification quality of natural burrows. This variation could be attributed to the variation in the architecture of the natural burrows, including size (e.g. diameter of the tunnel, length of the non-curved section), shape (e.g. straightness, how uniform the diameter is) and the surface or material of the tunnel (e.g. smooth hard-packed dirt, stone on one or more sides, loose or lumpy dirt) (Li, 2020). There are many rocks and stones on Manx Shearwater colonies on Lundy, which could force the Manx Shearwater burrows to turn a corner. We expect a long straight cylindrical burrow entrance will have a clear amplifying effect (Keefe, 1984), while one that turns just behind the calling bird will have very little, and smooth hard surfaces will reflect more than rough or soft surfaces (Berry *et al*, 2016). Our findings highlight that burrow structure and the application of artificial nest boxes have effects on the animal's signal propagation.

Our findings suggested that the quality of a burrow could be partly affected by how well it amplifies calls. It is possible that the birds pre-breeding activities (re-excavation) could manipulate the amplification. However, a pilot study did not find a link between whether a burrow was occupied and it's acoustic qualities (Ren, 2022). Burrow choice was not associated with burrow quality with respect to likelihood of flooding either, presumably because the birds had no way to assess the quality of the burrow other than breeding in it (Thompson, 1987). Factors that drive Manx Shearwater's burrow choices other than the previous breeding outcome remain unknown, and whether burrow shape is important for Manx Shearwater breeding biology remains uncertain.

Apart from the vocalisations of the mate, other cues could also play a part in Manx Shearwaters' locating their nest burrows. Although Manx Shearwaters' eyes are not strongly adapted to night vision, visual cues could still play a role, for example, after they land on the colony (Brooke, 1990). Proprioception, the sense of self-movement, force, and body position, could also play a part in reaching the burrow (Brooke, 1990). While it is unclear whether smell is used as a cue for locating burrows by Manx Shearwaters, it might be used by other petrels (Brooke, 1990).

Our studies on vocalisation behaviours of Manx Shearwaters on Lundy have contributed to the knowledge of the natural history of the species as well as animal communication behaviour in general. Further research on vocalisations in Manx Shearwaters is ongoing. An incoming PhD project will study of the development of vocal behaviour and individual vocal signatures in juveniles, and the degree to which offspring vocalisations resemble those of their parents. Furthermore, the recordings taken of Manx Shearwaters on Lundy for this and previous studies are also used to develop methods to separate overlapping vocalisations using deep learning, which continues to contributes to the methodology of bioacoustics analysis (e.g. Liu, 2023), with the aim of using machine learning to semi-automate the currently labour-intensive breeding census of this species. There is clearly still much to learn about the vocalisations of these magnificent seabirds.

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