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SHORT NOTE

Do flesh-footed shearwaters (*Puffinus carneipes*) use leaves as "home insulation"?

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Shearwaters in the genus *Puffinus* nest in burrows, typically on predator-free islands. Their burrows usually contain a single nesting chamber (Warham 1990, 1996) except at high densities when several pairs may nest in a common burrow system with many galleries (Hamilton 2000). While these species are adapted to cold climates, they may have more difficulties withstanding hot weather. Research on thermoregulation in wedge-tailed shearwaters (*Puffinus pacificus*) showed high energy demands on birds in warm conditions as they tried to maintain their body temperature within a thermally neutral zone 10 – 30° C (Whittow *et al.* 1987). Similar results have been found for little penguins (*Eudyptula minor*; Stahel & Nicol 1982).

During 4 years between 2007 and 2014 we studied the ecology of flesh-footed shearwaters (*Puffinus carneipes*), at islands in northern New Zealand: Lady Alice Island/Mauimua, Ohinau Island and Titi Island (respectively 35.89° S, 174.71° E; 36.72° S, 175.88° E; 40.95° S, 174.13° E). During this time, >1,000 breeding burrows were surveyed for their contents. All sites were situated in areas of native forest. For flesh-footed shearwaters, a proportion of the burrow entrances were filled with leaves at each of the sites surveyed. This made it difficult to detect burrows, so our search techniques were refined to include checking under leaf litter and where dimples in the forest understorey landscape were detected. Breeding birds were found in a proportion of burrows 'camouflaged' in this way. In January 2014, at Ohinau Island, a number of burrows were noted, as elsewhere, with leaves covering the burrow entrances. We measured the occurrence of leaf covering of burrows and found on average 61% (*s.d.* = 0.24) of occupied burrows were covered with leaves in 4 colonies ($n = 28 – 40$), while only 35% (*s.d.* = 0.05) of burrows that were empty had leaf coverings. These differences were significantly different ($P = 0.05$, 1-tailed t-test, unequal variances),

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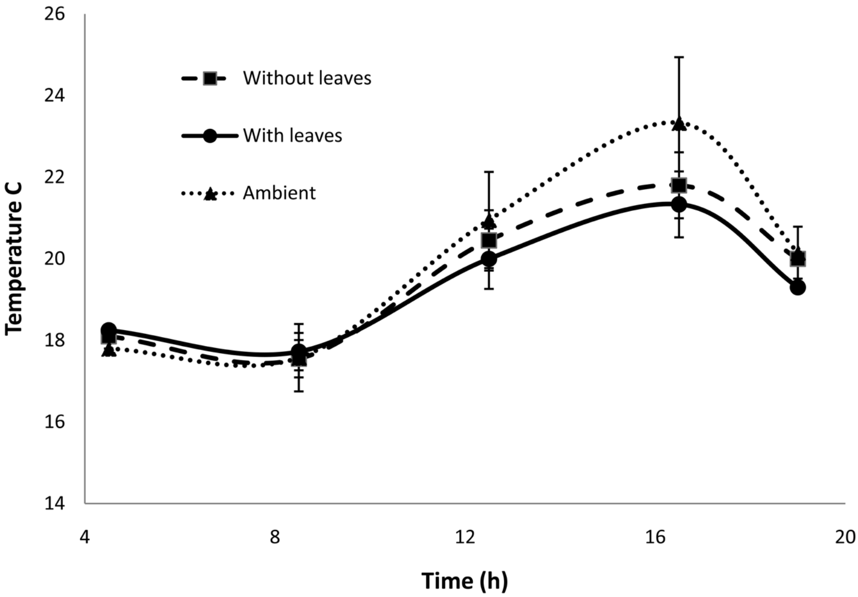

Fig. 1. Average temperature (standard-deviation error bars) measured throughout the day for 4 days in 2 sets of paired burrows at Ohinau Island, New Zealand, with leaves (solid line) and without leaves (dashed line) and for the ambient temperature (dotted line).

suggesting that the occurrence of leaves in burrows may not be due to chance alone.

As we were studying the behaviour of breeding birds at this site, a number of birds in study burrows were marked with white correcting fluid on the head to identify them. On one evening, a marked bird was seen at the surface, having left its burrow, before departure to sea. Over a period of 5 minutes, the bird moved from its borrow entrance to a pile of leaves about 25 cm away, and moved 2 -3 leaves across to its burrow entrance while we watched. The burrow entrance was already partially filled with leaves when we encountered the bird. The bird later departed to sea, leaving its partner and egg in the leaf-filled burrow. We only observed this behaviour once, by chance. As our main activity at the island was to monitor population sizes and foraging ecology, opportunities to do detailed behavioural observations of individuals were limited.

On the basis of this single observation, we decided to assess the potential benefits of this activity for the shearwaters. We considered 3 possible explanations: (a) an anti-predator or anti-competitor mechanism – the birds might seek to hide their nest to avoid detection by other species, (b) a thermal or insulating benefit, such as raising the temperature of the burrows, or moderating the effects of warm temperatures or low humidity on hot slopes, or (c) that the birds were bringing nesting material into their burrows. We were able to assess the temperature hypothesis only with the time and equipment available, so we measured temperature changes at burrows.

We measured temperature in 2 pairs of burrows for two 48 h periods each, at intervals of 4 to 8 hours between 04.00 h and 20.00 h daily. Temperature changes were compared between a 'leaf-filled' or 'empty' burrow entrance treatment. We chose burrows which were located adjacent to one another and with similar length. We only used empty burrows to ensure our measures were not confounded by the activities of birds within the burrows. One of each pair of burrows had 2 handfuls of leaves stuffed in the entrance, about an equivalent volume to the quantities of leaves found in shearwater burrows naturally; the other was left open. An electronic temperature probe was inserted ~50 cm into the burrow and the temperature read after 5 minutes for each of the paired burrows. After 24 h, we switched the treatments between the burrows.

Our results suggest that one potential benefit of the leaves is to buffer temperatures, both during daytime and night-time. The temperature in the insulation treatment burrows was slightly lower during daytime and marginally higher during night-time than the uninsulated burrow, or the ambient temperature (Fig. 1). Our data were not sufficient to carry out statistical testing, but suggest that temperature buffering may be occurring. We were unable to test for humidity effects, but it is likely that temperature and humidity effects work would in concert.

Birds, along with other species (Bradshaw & Maine 2009) use behavioural mechanisms to regulate temperature and humidity (Coulombe 1971). Our observation suggests that flesh-footed shearwaters in New Zealand may be using leaves to reduce the effects of warm daytime temperatures and cooler night-time temperatures, as a form of "home-insulation." Humidity may also be affected, although it was not tested here. This may be a widespread behaviour, with the species occurring mainly in sub-tropical areas of the Pacific Ocean, Tasman Sea and Indian Ocean (Brooke 2004). Thermoregulation and behavioural mechanisms to avoid heat and cold stress have been researched in other species of seabirds, but to date, reports on birds using behaviours to mitigate heat stress, wind or chilling have only included behaviours such as sheltering in burrows, use of shade, hyper-ventilating, or wetting bodies to regulate temperature (Schreiber 2003). Use of objects as tools to moderate temperature has not been reported before. Further investigation of the benefits of this behaviour for the shearwaters is warranted. It may be interesting to examine the role of aspect and exposure to sunlight on the behaviour of shearwaters at their burrows. At many of the sites where flesh-footed shearwaters breed, there is dense forest canopy and some areas are deeply shaded, and some appear to be better ventilated or less sunny than others. It would be interesting to determine if the relative frequency of leaf occurrence is related to the physical parameters of the colonies or individual nests.

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