Wilson Bull., 103(1), 1991, pp. 126–130

Nest-site selection by the Herald Petrel and White-tailed Tropicbird on Round Island, Indian Ocean.—Nest-site selection is an important aspect of fitness affecting the survival of incubating adults and their reproductive success. Thermal stress is a major problem for seabirds on tropical oceanic islands (Salzman 1982). The adaptation for burrow nesting found in many species of Procellariidae protects from both predators and thermal stress, and is found in both temperate and tropical zone species. Unlike most Procellariids, however, the Herald Petrel (*Pterodroma arminjoniana*) is a surface nester. We examined its nest-site selection in comparison with that of nearby White-tailed Tropicbirds (*Phaethon lepturus*) on Round Island, 20 km north of Mauritius, in the western Indian Ocean.

Since this nearly predator-free island is largely devoid of vegetation, and the flat rocky surfaces radiate heat intensely (Gill et al. 1970), we hypothesized that birds nesting there would select sites to avoid both direct solar radiation and re-radiation. Re-radiation must be considered a major factor in evaluating heat load (e.g., Dawson 1972). Gill et al. (1970) remarked on the consistent placement of petrel nests on Round Island to maximize midday shade.

Additional factors affecting nest-site selection include competition and predation. Competition for nest sites is expected to be severe where available sites are limited, and where severe selection factors (such as predation or thermal stress) affect reproductive outcome (see references in Cody 1985). Seabirds nest on remote islands partly to escape mammalian predation. Small islands may not have sufficient food to maintain a predator's population outside of the seabird breeding season (Lack 1968). Exceptions occur, however, where there are introduced predators such as rats (Grant et al. 1981, Moors and Atkinson 1984). Island-nesting seabirds, however, are exposed to avian predators, some which are non-breeding visitors, and others which nest on the same island or on nearby mainlands.

The Herald Petrel of the Pacific and the South Trinidad Petrel of the Atlantic have been treated as separate species, *Pterodroma heraldica* and *P. arminjoniana,* respectively, but current taxonomic treatment (American Ornithologists' Union 1983), considers them subspecies. The colloquial name Herald has been applied while *arminjoniana* has priority as the specific name (Gochfeld et al. 1988). The Herald Petrel (including the South Trinidad Petrel) occurs at tropical and subtropical latitudes in the Atlantic, Indian and Pacific Oceans. The Indian Ocean population breeds only on Round Island. Based on plumage pattern and measurements, which are similar to the birds of South Trinidad Island, the Round Island petrels are referred to the nominate subspecies. Its presence as an Indian Ocean breeder was discovered only in 1949 from three specimens sent to Murphy (Murphy and Pennoyer 1952). Nonetheless, at least in October and November, the species is conspicuous at Round Island, one or more individuals being almost always in evidence wheeling over the rocky slopes where it nests.

There is a considerable literature on nest sites of petrels, including underground burrows (Brooke 1978, Byrd et al. 1983, Floyd and Swanson 1983, Schramm 1983), rock cavities, crevices, and fissures (Maher 1962, Teixeira and Moore 1983) or both (Warham et al. 1977, Boersma et al. 1980), but there is little information on the Herald Petrel. Murphy (1915) visited, but did not land on South Trinidad(e) in April 1913, and saw them "nidificating or perhaps only resting, in water-worn cells of the rock." Mathews (1936) emphasized the surface-nesting behavior of this and several other petrels and suggested it as a subgeneric character. Gill et al. (1970) described and illustrated the nesting behavior of *P. arminjoniana* on Round Island, finding only surface-nesting birds, and noted that nests were always sheltered from the midday sun either by plants or overhanging rocks. King (1984) reports a breeding range extension to Australia but provided few details on nesting.

The previously published descriptions of Herald Petrel nest sites do not compare these with unused but available habitat. In this paper, we compare the nest sites of a small subcolony of petrels on Round Island with nearby unused sites and with those used by White-tailed Tropicbirds nesting among them. We visited Round Island on 3 November 1989 and made our observations in the middle of the day when solar radiation was the most extreme. Round Island (150 ha) is a volcanic rock with a maximum elevation of 262 m. The island is predominantly smooth fissured rock with limited areas of soil suitable for burrowing species. Prior to elimination of goats and rabbits, the island vegetation was virtually destroyed, but there has been substantial recovery in recent years. Further description of Round Island can be found in Gill et al. (1970).

Round Island supports nesting Wedge-tailed Shearwaters (*Puffinus pacificus*), White-tailed and Red-tailed tropicbirds (*Phaethon rubricauda*) as well as Herald Petrels. Nearby Serpent Island supports a large colony of terns and boobies, but these have never been found nesting on Round Island. The Wedge-tailed Shearwaters excavate nest burrows in the soil areas of the island, whereas the other species nest in the rocky habitat. A nest survey in September 1989 found about 75 petrel nests and estimated as many as 150 for the island as a whole (C. Taylor, pers. comm.). Gill et al. (1970) estimated a maximum of 75 pairs of petrels on Round Island in October 1964. They provide evidence that the birds nest throughout the year, hence the Indian Ocean population may be 3–4 times that found on the island at any one time. To avoid undue disturbance to this rare bird, we examined only one typical subcolony.

The subcolony we examined had 16 nests of Herald Petrel and six nests of White-tailed Tropicbird, and encompassed a 15 × 50 m area, about two thirds of the way up the southwest slope of the island, just below and to the south of the subcolony described by Gill et al. (1970, p. 517). The area was mostly barren with one palm tree and scattered clumps of grass. The overall slope was 30–35°. The petrels nested only in rock cavities with overhanging rock, so we recorded characteristics at the nests and at the closest cavity that was at least 1 m away (assuming they might not tolerate a neighbor that was too close). We also recorded characteristics at the White-tailed Tropicbird nests and at matched cavities for these nests as well. Characteristics recorded at each cavity included contents, height, width, and depth of cavity, percent of rock cover over incubating adult or cavity, percent grass within 0.5 m in front of the cavity, depth of the shade (how much of the floor of the cavity was shaded, measured from back wall to edge of shadow), and percent of floor of cavity that was shaded. Fourteen petrel nests contained eggs, one had a young pale grey downy chick, and one was empty. Usually, the incubating adults did not move while we measured the cavity and photographed the nest site. We used Mann Whitney *U*-tests to contrast differences between nests and unused cavities.

In all cases, as mentioned by Gill et al. (1970), the petrels and tropicbirds were completely shaded from the sun at midday and were often partially protected by grass that provided additional shade. Usually, the petrels were incubating their egg, although two birds merely sat beside them. Inter-nest distance between petrels ranged from 2.2 to 10 m, and petrels on adjacent nests could not see their neighbors. Characteristics of nest cavities and unused cavities are shown on Table 1.

We contrasted the cavity size, vegetation, and shade characteristics at the 16 petrel nests with those of the unoccupied cavity nearest each nest (Table 1). We recognize that some of these unoccupied cavities might be occupied at other times. Rock cover around the cavity did not differ for nests and control sites, nor did the height or width of the cavities. Petrel nests were in deeper cavities (35 vs 15 cm), and accordingly there was more shade within 50 cm of the egg, as well as a greater depth of shade on the cavity floor. These measurements were made between 11:45 and 13:30, taking advantage of essentially noon conditions.

TABLE 1

CAVITY CHARACTERISTICS FOR NESTS OF THE HERALD PETREL AND WHITE-TAILED TROPICBIRD ON ROUND ISLAND, MAURITIUS

	Herald Petrel		White-tailed Tropicbird		Interspecies comparison
	Controls	Nests	Controls	Nests	
Rock cover	14.2 ± 22.4	10.8 ± 10.6	19.7 ± 21.7	10.5 ± 8.4	$U = 47$
	5	10	11	13	ns
	$U = 87$	ns	$U = 17$	ns	
Cavity height	29.8 ± 17.4	31.4 ± 11.0	52.7 ± 43.7	55.2 ± 7.8	$U = 6$
	27	29.5	44	59.5	$P < 0.002$
	$U = 122$	ns	$U = 18$	ns	
Width	53.8 ± 35.3	54.0 ± 13.9	48.7 ± 37.5	46.8 ± 9.4	$U = 33$
	42	55.5	45	48.5	ns
	$U = 102$	ns	$U = 18$	ns	
Depth	15.1 ± 10.4	35.4 ± 13.0	11.8 ± 6.2	38.7 ± 7.0	$U = 31$
	13	32.5	13.5	38.5	ns
	$U = 68$	$P < 0.05$	$U = 0$	$P < 0.001$	
Percent shade	32.8 ± 28.9	53.9 ± 16.5	8.2 ± 10.3	74.0 ± 15.4	$U = 18$
	25	55	4.5	80	$P < 0.05$
	$U = 75$	$P < 0.05$	$U = 0$	$P < 0.001$	
Percent grass	4.4 ± 9.8	29.7 ± 22.0	0.8 ± 1.9	37.7 ± 18.1	$U = 37$
	0	30	0	39	ns
	$U = 4$	$P < 0.0001$	$U = 0$	$P < 0.001$	
Shade depth	9.4 ± 9.4	25.2 ± 9.7	6.7 ± 6.2	32.8 ± 5.5	$U = 20$
	7	25.5	5.5	34	$P < 0.05$
	$U = 6$	$P < 0.001$	$U = 0$	$P < 0.001$	
Number	16	16	6	6	

For each variable, the first line gives the mean ± SD, the second line median, and the third line the Mann-Whitney U score and its associated probability comparing nests versus controls for each variable for each species.

Cavities occupied by petrels had significantly more vegetation around the entrance than did control sites perhaps because over time the soil is fertilized by droppings from the chicks.

The six tropicbird nests found in the vicinity of the petrel cluster were examined for comparison. The same comparisons held for the tropicbirds. Their nests did not differ from controls in the amount of rock cover or in the height and width of the cavity, but they occupied significantly deeper cavities that cast more shade. Moreover, they had extensive vegetative cover at the mouth of their nest cavities, such that in some cases the incubating bird was nearly completely hidden from view.

Comparing the tropicbird nest cavities with those of the smaller petrel revealed no difference in the width or depth of their cavities, but tropicbirds preferred higher cavities ($P < 0.002$) with significantly more shade ($P < 0.05$, Table 1).

The significant differences we found between petrel nests and unused cavities seemed to reflect thermal constraints. Petrel nests were always in cavities that were deep enough to cover them, had large enough rock overhangs to provide shade at midday, and had some vegetation that would provide additional shade in the afternoon. Thermoregulation is an important consideration for a variety of seabirds on oceanic islands (Howell and Bartholomew 1961).

Moreover, all petrel nest cavities faced downward toward the sea which would allow updrafts of cooling winds, while facilitating rapid departure from the nest. The depth of shade on the floor of the cavity is probably a significant factor which reduces the re-radiation received by the incubating bird and later its chick. Tropicbirds also selected cavities that were large and shaded at midday. The tropicbirds were located in higher (but not wider or deeper) cavities than the petrels. Prys-Jones (1980) reported that White-tailed Tropicbirds on Aldabra selected nest sites that were partly concealed from above, and 96% were enclosed by rock, in contrast to Red-tailed Tropicbirds for which 88% of the nests had only vegetative cover. At Culebra, Puerto Rico, we have seen White-tailed Tropicbirds nesting in small rocky caves, crevices, and tunnels, all nearly enclosed by rock. By contrast, Gill et al. (1970) reported Red-tailed Tropicbirds nesting in cavities similar to those of petrels and White-tailed Tropicbirds nesting in vegetation. Phillips (1987) reported that 80% of all White-tailed Tropicbird nests on Cousin Island, Seychelles, were in shallow caves and cavities or in the shade of rock overhangs and boulders. The sites we studied at Round Island were similar to those on the Seychelles, and it appears that it is concealment and protection, rather than the choice of rock or vegetation per se, which is characteristic of White-tailed Tropicbirds.

Acknowledgments.—We thank R. Rowlett and J. Pierson for providing transportation to Round Island and C. Taylor for kindly guiding us around the island and providing an estimate of the number of birds on the island.

LITERATURE CITED

AMERICAN ORNITHOLOGISTS' UNION. 1983. Check-list of North American birds. 6th ed. A.O.U., Washington, D.C.

BOERSMA, P. D., N. T. WHEELWRIGHT, M. K. NERINI, AND E. S. WHEELWRIGHT. 1980. The breeding biology of the Fork-Tailed Storm-Petrel (*Oceanodroma furcata*). Auk 97: 268–282.

BROOKE, M. DE L. 1978. Some factors affecting the laying date, incubation and breeding success of the Manx shearwater, *Puffinus puffinus*. J. Anim. Ecol. 47:477–495.

BYRD, G. V., D. I. MORIARTY, AND B. G. BRADY. 1983. Breeding biology of Wedge-tailed Shearwaters at Kilauea Point, Hawaii. Condor 85:292–296.

CODY, M. L. (ed.). 1985. Habitat selection in birds. Academic Press, New York, New York.

DAWSON, T. J. 1972. Likely effects of standing and lying on the radiation heat load experienced by a resting kangaroo on a summer day. Aust. J. Zoology 20:17–22.

FLOYD, R. B. AND N. M. SWANSON. 1983. Wedge-tailed Shearwaters on Muttonbird Island: an estimate of the breeding success and the breeding population. Emu 82:244–250.

GILL, F. B., C. JOUANIN, AND R. W. STORER 1970. Notes on the seabirds of Round Island, Mauritius. Auk 87:514–521.

GOCHFELD, M., J. BURGER., J. SALIVA, AND D. GOCHFELD. 1988. Herald Petrel new to the West Indies. Amer. Birds 42:1254–1258.

GRANT, G. S, T. N. PETTIT, AND G. C. WHITTOW. 1981. Rat predation on Bonin Petrel eggs on Midway Atoll. J. Field Ornith. 52:336–338.

HOWELL, T. R. AND G. A. BARTHOLOMEW. 1961. Temperature regulation in nesting Bonin Island Petrels, Wedge-tailed Shearwaters, and Christmas Island Shearwaters. Auk 78: 343–354.

KING, B. R. 1984. The Herald Petrel *Pterodroma arminjoniana heraldica* breeding on Raine Island, Qld. Emu 84:246–247.

LACK, D. 1968. Ecological adaptations for breeding in birds. Methuen & Co., London, England.
MAHER, W. J. 1962. Breeding biology of the Snow Petrel near Cape Hallett, Antarctica. Condor 64:488–499.
MATHEWS, G. M. 1936. Dove-like petrels of the genus *Pterodroma.* Ibis 1936:376–377.
MOORS, P. J. AND I. A. E. ATKINSON. 1984. Predation of seabirds by introduced animals, and factors affecting its severity. Pp. 667–690 *in* Status and conservation of the world's seabirds (J. P. Croxall, P. G. H. Evans and R. W. Schreiber, eds.). I.C.B.P. Technical Public. No 2, Cambridge, England.
MURPHY, R. C. 1915. The bird life of Trinidad Islet. Auk 32:332–348.
——— AND J. M. PENNOYER. 1952. Larger petrels of the genus *Pterodroma.* Am. Mus. Novitates 1580:1–42.
PHILLIPS, N. J. 1987. The breeding biology of White-tailed Tropicbirds *Phaethon lepturus* at Cousin Island, Seychelles. Ibis 129:10–24.
PRYS-JONES, R. P. 1980. Breeding periodicity, nesting success and nest site selection among Red-tailed Tropicbirds *Phaethon rubricauda* and White-tailed Tropicbirds *P. lepturus* on Aldabra Atoll. Ibis 122:76–81.
SALZMAN, A. G. 1982. The selective importance of heat stress in gull nest location. Ecology 63:742–751.
SCHRAMM, M. 1983. The breeding biologies of the petrels *Pterodroma macroptera, P. brevirostris* and *P. mollis* at Marion Island. Emu 83:75–81.
TEIXEIRA, A. M. AND C. C. MOORE. 1983. The breeding of the Madeiran Petrel *Oceanodroma castro* on Farilhao Grande, Protugal. Ibis 125:382–384.
WARHAM, J., B. R. KEELEY, AND G. J. WILSON. 1977. Breeding of the Mottled Petrel. Auk 94:1–17.

JOANNA BURGER AND MICHAEL GOCHFELD, *Biological Sciences, Rutgers Univ., Piscataway, New Jersey, 08855 and Environmental and Community Medicine, UMDNJ-Robert Wood Johnson Medical School, Piscataway, New Jersey, 08854.* *Received 1 May 1990, accepted 19 Sept. 1990.*

Wilson Bull., 103(1), 1991, pp. 130–132

Tristan Thrushes kill adult White-bellied Storm-Petrels.—The Tristan Thrush (*Nesocichla eremita*) is restricted to the Tristan da Cunha group of islands in the central South Atlantic Ocean. It has a catholic diet, taking a range of invertebrates and fruits, and scavenging carrion from dead birds and fishes (Hagen 1952, Richardson 1984). The species has several structural adaptations to life on oceanic islands, including fairly small, rounded wings, a reduced sternum, and robust legs and feet. These adaptations are associated with its more cursorial life-style and reduced flight capabilities compared to most members of the Turdidae. However. the most distinctive feature of the Tristan Thrush is its concave, brush-tipped tongue (Lowe 1923) that is used to extract the contents of eggs. Tristan Thrushes use their large, strong bills to make holes in seabird eggs which are a seasonally abundant resource at the Tristan islands. Tristan Thrushes also kill and eat nestlings of other landbirds on the islands, including the buntings *Nesospiza* spp. and the Inaccessible Island Rail (*Atlantisia rogersi*) (Collar and Stuart, 1985, pers. obs.). However, there are no reports of Tristan Thrushes killing fully grown birds.

We visited Inaccessible Island for four months between October 1989 and March 1990. During this period, Tristan Thrushes were seen to attack and kill fully grown White-bellied