

COMMON NESTING HABITATS AND WEIGHTS AT FLEDGING OF WEDGE-TAILED SHEARWATERS ON TERN ISLAND, HAWAII

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The Wedge-tailed Shearwater (*Puffinus pacificus*) is a common seabird in the Hawaiian Islands, breeding from Kure Atoll in the northwest to offshore islets near Maui in the south (Richardson 1957, Harrison 1990, Whittow 1997, Spear and Ainley 1999, Pyle and Pyle 2009). The highest concentration of breeding Wedge-tailed Shearwaters is in the northwestern Hawaiian Islands, where Pyle and Pyle (2009) estimated over 228,000 pairs. The largest colonies are on Laysan (150,000 pairs), Nihoa (35,000 pairs), and Lisianski (20,000 pairs) (Harrison 1990, USFWS 2005, Pyle and Pyle 2009). In the southeastern Hawaiian Islands, the population of the Wedge-tailed Shearwater has been estimated at roughly 67,000 pairs, with the largest colonies on O'ahu (30,550 pairs) and Ni'ihau (25,000 pairs) (VanderWerf et al. 2007, Pyle and Pyle 2009). The goals of our study were to estimate the number of Wedge-tailed Shearwaters fledging in 2010 on Tern Island, the main island in the atoll of French Frigate Shoals, in the northwestern Hawaiian Islands, to identify common nesting habitats in relation to vegetation cover and soil type, and to investigate differences between natural and artificial nests in fledglings' weight and date of fledging.

For one month (18 October–18 November 2010) we searched the entire island for chicks, checking every bush, burrow, building, pipe, and debris pile, and banding each chick with a uniquely numbered U.S. Geological Survey metal band. Additionally, we recorded information on nest type, soil type, and vegetation cover over the nest at time of capture. We categorized nests as natural burrows, natural ground nests, nest boxes/huts, other artificial sites, or unknown (Figures 1 and 2). Natural burrows consisted of burrows dug by Wedge-tailed Shearwaters in a natural setting without support or cover by man-made structures. Natural ground nests consisted of eggs laid on the bare ground, often under vegetation, without support or cover by man-made structures. Nest boxes/huts were man-made structures built for nesting of burrowing seabirds. Other artificial nests consisted of burrows or ground nests with support or cover by man-made structures. This category includes nests inside or under buildings, pipes, debris, or sidewalks. The category of "unknown" encompasses nests whose location could not be determined because the chick had become mobile and left its nest. Using stratified random sampling, we weighed 40 chicks (10 from each nest type) three times per week with a 1000-gram Pesola scale and monitored them for survival to assess differences in fledglings' weight and departure date by nest type. We tested for statistical differences ($\alpha = 0.05$) between nest types with a Mann–Whitney pairwise comparison in the program PAST, version 2.17b (Hammer et al. 2001).

We banded 410 chicks in 2010 and found only two banded chicks dead before fledging, representing an estimated maximum number of 408 chicks fledged. This is 259 chicks fewer than in 2009 (667 chicks) and the lowest number of fledglings since 2005 (364 chicks) (USFWS unpublished data). Since 1990, however, the

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Figure 1. Common types of Wedge-tailed Shearwater nests on Tern Island. A, natural burrow; B, natural ground nest.

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Figure 2. Common types of Wedge-tailed Shearwater nests on Tern Island. A, nest box/hut; B, artificial nest.

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Wedge-tailed Shearwater population on Tern Island has increased slowly but steadily (USFWS unpublished data). As on most other islands where Wedge-tailed Shearwater nesting has been studied (Gallagher 1960, Shallenberger 1973, Byrd 1979, Byrd et al. 1983, Harrison 1990, Sievert 1996), the most common nest type on Tern Island was naturally dug burrows, which accounted for 62.0% ($n = 254$) of all nests. This type was followed by artificial nests at 23.2% ($n = 95$), natural ground nests at 7.1% ($n = 29$), unknown nest sites at 4.9% ($n = 20$), and artificial nest boxes at 2.9% ($n = 12$). Humus was the most common soil type for natural burrow and ground nests, accounting for 85.9% ($n = 243$) of all nests. Other soil types in which the shearwaters nested were fine sand and rock at 13.1% ($n = 37$), all small rock at 0.7% ($n = 2$), and sand at 0.4% ($n = 1$). Although we took no standardized measurements, burrows dug in sand were apparently deeper than those in humus. No vegetation cover was the most common cover type for natural burrow and ground nests, accounting for 38.9% ($n = 110$) of all nests, followed by Tree Heliotrope (*Heliotropium foertherianum*) at 35.3% ($n = 100$), *Lepturus* (*Lepturus repens*) at 21.6% ($n = 61$), native goosefoot (*Chenopodium* sp.) at 2.12% ($n = 6$), dead logs at 1.41% ($n = 4$), and Morning Glory (*Ipomoea pes-caprae*) at 0.71% ($n = 2$).

We found no significant differences by nest type in weight at initial banding, fledging, or maximum weight achieved (Mann-Whitney pairwise comparison, $P > 0.05$; Figure 3). But natural burrows and artificial nests differed in the chicks' date of fledging and minimum recorded weights. Chicks in artificial nests fledged significantly later and had lower minimum recorded weights than those in natural burrows (Figure 3). Fledgling success was 100% from all types of nests except natural ground nests, from which we recovered two dead chicks before fledging (Table 1).

Proper conservation of burrow locations is essential for the long-term conservation of breeding colonies of the Wedge-tailed Shearwater, as most birds return to their natal island to breed and reuse burrows for nesting (Munro 1967, Shallenberger 1973). On Mānana island, off O'ahu, out of 32 Wedge-tailed Shearwaters banded by Shallenberger (1973), 14 returned to the same burrow the following year to nest, 11 were in burrows less than 3 meters away, and 6 nested on the surface close to their burrow from the previous year. As we noted, ground nesting can be problematic for Wedge-tailed Shearwaters, as ground nests were the only nest type at which we found dead chicks. In another study on Tern Island, Sievert (1999) found ground-nesting Wedge-tailed Shearwaters to have a success rate of only 2% because they were more exposed to a hot microclimate than were chicks in shaded burrows. Exposure to the tropical sun on Tern Island increases incubating adults' stress from heat and water loss, making the adult more likely to abandon the egg during the day (Howell and Bartholomew 1961, Sievert 1996).

For conservation of the Wedge-tailed Shearwater on Tern Island, we recommend maintenance of existing nesting burrows and locations. Efforts should focus on conservation of areas with humus soil type and revegetation of bare areas with Tree Heliotrope and *Lepturus*. Conserving and restoring nesting habitat for the Wedge-tailed Shearwater may in turn help conservation efforts for the Tristram's Storm-Petrel (*Oceanodroma tristrami*; McClelland et al. 2008), a near-threatened (BirdLife International 2008) species of conservation concern (USFWS 2002), by reducing burrow-nesting seabirds' competition for nest sites (McClelland et al. 2008).

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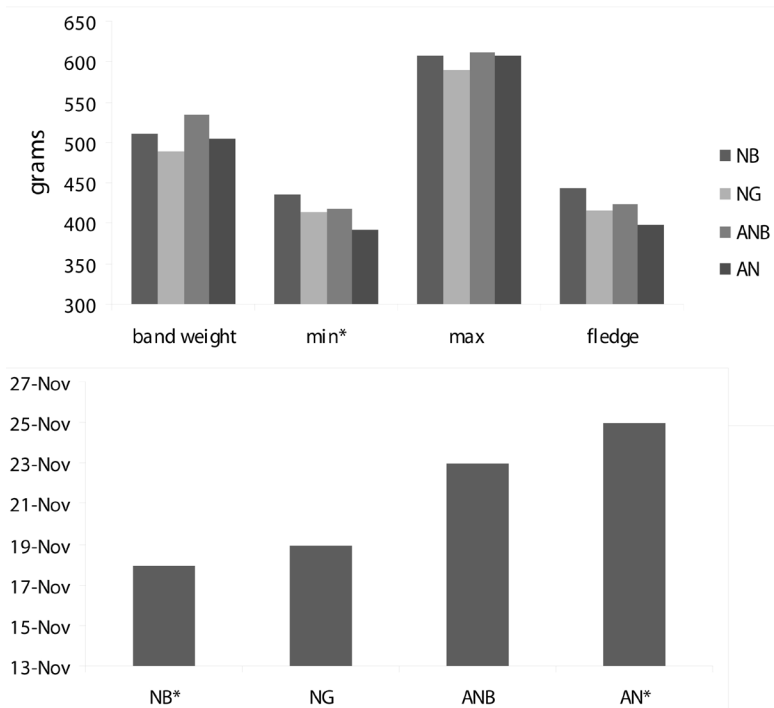


Figure 3. Comparison by nest type of weights and dates of departure of Wedge-tailed Shearwater fledglings on Tern Island, French Frigate Shoals, 2010. NB, natural burrows; NG, natural ground nests; ANB, artificial nest boxes; AN, artificial nests. Asterisks indicate a significant difference between means of fledglings in artificial nests and natural burrows (Mann–Whitney pairwise comparison, $P = 0.037$) and in date of fledging (Mann–Whitney pairwise comparison, $P = 0.037$).

LITERATURE CITED

- BirdLife International. 2012. Species factsheet: *Oceanodroma tristrami*; www.birdlife.org (21 October 2012).
- Byrd, G. V. 1979. Artificial nest structures used by Wedge-tailed Shearwaters on Kaua'i. 'Elepaio 40:10–12.
- Byrd, G. V., Moriarty, D. I., and Brady, B. G. 1983. Breeding biology of Wedge-tailed Shearwaters at Kilauea Point, Hawaii. Condor 85:292–296.
- Gallagher, M. D. 1960. Bird notes from Christmas Island, Pacific Ocean. Ibis 102:489–502.
- Hammer, O., Harper, D.A.T., Ryan, and P. D. 2001. PAST: Paleontological statistics software package for education and data analysis. Palaeontologia Electronica 4(1); http://palaeo-electronica.org/2001_1/past/issue1_01.htm.
- Harrison, C. S. 1990. Seabirds of Hawaii: Natural History and Conservation. Cornell Univ. Press, Ithaca, NY.

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Table 1 Weights and Dates of Departure of Wedge-tailed Shearwater Fledglings on Tern Island, French Frigate Shoals, 2010

Nest	Weight (g)			At fledging	Date of fledging
	At banding	Minimum	Maximum		
Natural burrows					
NB1	450	395	575	395	22 Nov
NB2	445	445	560	450	15 Nov
NB3	515	435	650	435	15 Nov
NB4	530	430	665	430	19 Nov
NB5	565	452	600	452	26 Nov
NB6	590	510	650	510	15 Nov
NB7	635	475	635	475	17 Nov
NB8	460	460	600	490	12 Nov
NB9	540	435	590	435	17 Nov
NB10	380	330	550	372	26 Nov
Mean	511	437	608	444	18 Nov
Natural ground nests					
NG1	510	450	530	450	17 Nov
NG2	460	420	575	Found dead	19 Nov
NG3	525	362	615	362	24 Nov
NG4	520	500	615	500	15 Nov
NG5			Found dead	18 Oct	
NG6	495	405	600	405	19 Nov
NG7	430	430	640	450	17 Nov
NG8	440	390	620	390	22 Nov
NG9	470	392	535	392	26 Nov
NG10	555	380	580	380	19 Nov
Mean	489	414	590	416	19 Nov
Artificial nest boxes					
ANB1	590	375	590	375	22 Nov
ANB2	420	381	585	402	11 Dec
ANB3	530	520	610	565	5 Nov
ANB4	470	400	590	400	17 Nov
ANB5	465	372	620	372	4 Dec
ANB6	500	451	620	451	6 Dec
ANB7	655	465	660	465	8 Nov
ANB8	560	405	570	405	19 Nov
ANB9	590	450	690	450	22 Nov
ANB10	575	361	590	361	30 Nov
Mean	536	418	613	425	23 Nov
Artificial nests					
AN1	450	312	585	312	2 Dec
AN2	505	417	625	417	24 Nov
AN3	455	412	575	412	26 Nov
AN4	555	382	605	382	4 Dec
AN5	405	302	465	302	2 Dec
AN6	480	425	650	425	22 Nov
AN7	585	475	630	530	12 Nov
AN8	480	340	620	340	17 Nov
AN9	590	430	670	445	22 Nov
AN10	550	432	650	432	26 Nov
Mean	506	393	608	400	25 Nov

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- Howell, T. R., and Bartholomew, G. A. 1961. Temperature regulation in nesting Bonin Island Petrels, Wedge-tailed Shearwaters, and Christmas Island Shearwaters. *Auk* 78:343–354.
- McClelland, G. T. W., Jones, I. L., Lavers, J. L., and Sato, F. 2008. Breeding biology of Tristram's Storm-Petrel *Oceanodroma tristrami* at French Frigate Shoals and Laysan Island, Northwest Hawaiian Islands. *Marine Ornithol.* 36:177–183.
- Munro, G. C. 1967. *Birds of Hawaii*. Charles E. Tuttle, Rutland, VT.
- Pyle, R. L., and Pyle, P. 2009. *The Birds of the Hawaiian Islands: Occurrence, History, Distribution, and Status*, version 1. B. P. Bishop Museum, Honolulu; <http://hbs.bishopmuseum.org/birds/rlp-monograph> (6 October 2011).
- Richardson R. 1957. The breeding cycles of Hawaiian seabirds. *B. P. Bishop Mus. Bull.* 218.
- SAS Institute, Inc. 2001. JMPIN, version 4.0.4. SAS Institute, Inc., Cary, NC.
- Sievert, P. R. 1996. Water and energy balance constraints on the nesting ecology of marine birds. Ph.D. dissertation, Univ. Pa., Philadelphia.
- Shallenberger, R. J. 1973. Breeding biology, homing behavior and communication patterns of the Wedge-tailed Shearwater *Puffinus pacificus chlororhynchus*. Ph.D. dissertation, Univ. Calif., Los Angeles.
- Spear, L. B., and Ainley, D.G. 1999. Seabirds in southeastern Hawaiian waters. *W. Birds* 30:1–32.
- U.S. Fish and Wildlife Service (USFWS). 2002. *Birds of conservation concern 2002*. U.S. Fish and Wildlife Service, Arlington, VA.
- U.S. Fish and Wildlife Service (USFWS). 2005. *Seabird conservation plan, Pacific region*. U.S. Fish and Wildlife Service, Migratory Birds and Habitat Programs, Pacific Region, Portland, OR.
- VanderWerf, E. A., Wood, K. R., Swenson, C., LeGrande, M., Eijzenga, H., and Walker, R. L. 2007. Avifauna of Lehua Islet, Hawai'i. Conservation and value management needs. *Pacific Science* 61:39–52.
- Whittow, G. C. 1997. Wedge-tailed Shearwater (*Puffinus pacificus*), in *The Birds of North America* (A. Poole and F. Gill, eds.), no. 305. Acad. Nat. Sci., Philadelphia.
- Whittow, G. C. 1979. The effects of heavy rain on nesting Wedge-tailed Shearwaters (Rabbit Island). *'Elepaio* 39:138–139.

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