A WOOD-CONCRETE NEST BOX TO STUDY BURROW-NESTING PETRELS

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Artificial nests have been a useful research and conservation tool for a variety of petrel species (Podolsky & Kress 1989, Priddel & Carlile 1995, De León & Mínguez 2003, Bolton *et al.* 2004). They facilitate observation and provide easy access, reducing overall disturbance to seabirds (Wilson 1986, Priddel & Carlile 1995) and increasing data-collection efficiency (Wilson 1986). Likewise, restoration programs using artificial nests have improved the number of potential nest sites, breeding success (Priddel & Carlile 1995, De León & Mínguez 2003, Bolton *et al.* 2004, Bried *et al.* 2009, McIver *et al.* 2016) and adult survival rates (Libois *et al.* 2012) of threatened petrel species.

An assortment of materials has been used to build artificial nest boxes for petrel species, such as wood (Sinclair 1981, Ainley *et al*. 1990, Miskelly *et al.* 2009), plastic (Priddel & Carlile 1995, De León & Mínguez 2003, Bolton *et al.* 2004), concrete (Carlile *et al.* 2012, McIver *et al*. 2016) and ceramic (McIver *et al*. 2016). Although those nests have shown high acceptance rates by seabirds, they have some disadvantages. For example, wooden boxes have a shorter lifespan (Bruns 1960), while plastic burrows are long-lasting. However, on sites where temperatures are high, plastic burrows could cause heat stress in chicks (Miskelly *et al.* 2009).

Commercial nest boxes made of wood-concrete—a mixture of concrete and sawdust—are extensively used in research into birds nesting in tree cavities. This material has advantages over wood due to its greater durability and weather resistance (Bruns 1960), offering better breathability over plastic and concrete. Tree cavity-nesting birds prefer wood-concrete over wooden nests (Browne 2006, García-Navas *et al.* 2008). A commercially available model designed for Common Kingfishers *Alcedo atthis* could be used for burrowing seabirds; however, it is relatively expensive and heavy. In this article, we present the design and the building process for a durable, lightweight and low-cost wood-concrete nest box suitable for studying a community of storm-petrel *Oceanodroma* species.

Three storm-petrel species breed at San Benito Islands, a group of three small islands off the Pacific coast of Baja California, Mexico (28°18′N, 115°35′W): Black Storm-Petrel *Oceanodroma melania*, Leach's Storm-Petrel *O. leucorhoa* and Least Storm-Petrel *O. microsoma*. These islands support around two million breeding pairs (Wolf *et al.* 2006). Black Storm-Petrels, the largest species, breed in natural crevices or in burrows build by other species, such as auklets (Ainley 1984, Velarde-González 2000). Leach's Storm-Petrels excavate their own burrows or use crevices among rocks (Ainley 1984). Least Storm-Petrels, the smallest species, commonly breed in clefts and cavities among and under rocks (Ainley 1984). For each of these species, which have a clutch size of one egg, there is an extended period of bi-parental care, and parents return to feed the chick only at night (Brooke 2004).

At San Benito West Island, 140 artificial wooden nests were deployed by previous researchers, beginning in 1999, to study the breeding biology of Cassin's Auklet *Ptychoramphus aleuticus*. Auklets readily accepted and used the nest boxes. In the first year, the occupancy rate was 30%, increasing to 80% in the fifth year (Shaye Wolf, pers. comm.). At San Benito, auklets breed earlier in the season than storm-petrels; therefore, the nest boxes become available for use by storm-petrels later in the season. Among the three storm-petrel species, Black Storm-Petrels have predominantly occupied artificial nest boxes, with occupancy rates ranging from 27% in the first year to 53% in the sixth year (Shaye Wolf, pers. comm.). A larger tunnel diameter (150 mm) for each nest box and the deployment of nest boxes to habitats preferred by Black Storm-Petrels likely contributed to this predominance.

Although these wooden nest boxes have provided suitable nesting sites, some have deteriorated and needed to be replaced. Thus, to facilitate the long-term study of the breeding biology of these three species, development and deployment of more durable nest boxes was required, and a wood-concrete nest box design was selected based on the development of a durable prototype before larger-scale manufacturing of nest boxes. Likewise, given that studies on natural nests have suggested that nest selection is related to body size (Ainley & Everett 2001, Ramos *et al.* 1997), we provided different tunnel diameters to improve occupancy of the two smaller species, Leach's and Least Storm-Petrels.

We built and installed 102 wood-concrete nest boxes at San Benito West Island from August to September 2012, when the breeding season of each storm-petrel species was well advanced (see downloadable online resources available from https://www.dropbox.com/s/ji4eshkrytfeayk/Appendix_A%20nest%20box%20for%20petrels.zip?dl=0). The nest boxes were constructed according to the design shown in Fig. 1a. Without entrance tunnel, the nest boxes measured 290 × 220 × 130 mm in length, width and depth, respectively. A removable lid provided researchers with easy access from above. Each nest was designed to be accessed by storm-petrels via a tunnel made of PVC corrugated pipe measuring 250 mm in length, which was aligned to the box (Fig. 1a). Wooden molds with three different entrance diameters (75, 63 and 50 mm) were designed to build the nest boxes. Each mold consisted of four parts (Fig. 1c): an inner piece, measuring 250 × 180 × 130 mm in length, width and height; an outer piece 290 × 220 × 130 mm in length, width and height; a ground plate, length and width exceeding 290 × 220 mm; and a lid, measuring 250 × 180 mm in length and width, with an inner frame of 20 mm (Fig. 1d). The front face of the inner piece contained a hole of the required tunnel diameter, into which a piece of smooth PVC pipe 10 cm in length was fitted loosely (Fig. 1e).

A wood-concrete mixture was prepared using 6 L of commercial cement, 12 L of sawdust, 200 g of calcium chloride (as a hardening agent) in granulated form, 5 mL of concrete sealer and 5 L of water. First, the dry ingredients (cement, sawdust and calcium chloride) were homogenously mixed. Then concrete sealer and 4.5 L of water were added and mixed. Finally, the remaining 0.5 L of the water was added. The mixture was left for 10 min to allow it to absorb the water. Before pouring into the forms, the consistency of the mixture was similar to that of mud. Because the construction was carried out on the island, the sawdust was previously sieved to remove any shavings or large pieces of wood, and fumigated with organic products and transported in sealed packages to avoid introducing non-indigenous species onto the island.

To build a nest box, molds were brushed with motor oil, and the inner and outer pieces were set up on the ground plate. To ensure that the lid would fit the box, an equal distance of 2 cm between the wall of the inner and the outer pieces was confirmed with a measuring tape. Next, the mixture was gradually poured into the space between the inner and outer pieces of the molds, which also were compressed firmly with a piece of wood. To stabilize the structure, two rectangular metal wires were placed in the spaces filled with the mixture—one close to the base and the other close to the top (Fig. 1e). A circular wire was also placed around the entrance hole. The smooth PVC pipe was inserted into the entrance to keep the space of the entrance tunnel free of mixture. When the mixture was almost dry on the surface, the molds and the PVC pipe were carefully removed, and the boxes were set in a sunny location to continue to dry and harden (Fig. 1f).

To build the lid, the lid mold was set up on one ground plate, brushed with motor oil and filled with the mixture. After approximately three hours, when starting to dry, the lid was removed from the mold to finish drying in a sunny location. Once boxes and lids were dry (after approximately 24 to 48 hours in the summer, depending on weather conditions), a corrugated PVC pipe 25 cm in length was fitted to the entrance with silicone sealant. Finally, a wood rasp was

Fig. 1. Wood-concrete nest box built for Storm-Petrels. Nest box (a) finished and (b) installed in the field. Molds used to build the nest box: (c) internal and external pieces over one ground plate, (c) lid mold and (d) setting up of the metal wire and smooth PVC pipe. Finished boxes and lids (f) drying in the sun. Photos: Florian Schaefer and Yuliana Bedolla.

used to adjust the opening to the tube and to fit the lid. The nest boxes did not include a floor; rather, the floor consisted of natural substrate to allow water and fecal waste to drain and to ensure that the egg would be laid on a level surface. Two people were able to build 10 nest boxes in one work day.

As birds are attracted by conspecific vocalizations and odor (Podolsky & Kress 1989, Buxton & Jones 2012), nests boxes were installed in areas with natural burrows and old wooden nests. A total of 72 nest boxes of different entrance sizes (diameter in millimeters) were deployed to areas adjacent to the old wooden nests: 10 units of 50 mm, 36 units of 63 mm and 26 units of 75 mm. Thirty nest boxes, each with a 50 mm tunnel diameter, were deployed near rock piles occupied by Least Storm-Petrels. Areas with gradual slopes (10° to 20°) and loose soil, which allowed easier excavation, were selected for the deployment of the nest boxes. The nest boxes were oriented in such a way that the nest entrances faced east to minimize accumulation of dirt and debris and to prevent prevailing winds from blocking the entrances. Individual boxes were placed 0.5 m to 3.0 m apart. Nest boxes were buried 5 cm into the ground. The sides were covered with fresh soil and small rocks. The lids were covered with a flat and heavy rock to prevent Common Raven *Corvus corax* predation, as has been observed in wooden nest boxes (authors' observations) and reported for artificial nest sites used by Ashy Storm-Petrel *O. homochroa* at Santa Cruz Island, California (McIver *et al*. 2016).

Visitation of nest boxes by storm-petrels at San Benito Island West was suspected by August 2013, when we detected storm-petrel feathers in nest boxes, although some feathers could have been blown in by the wind. That year, we relocated the 40 nest boxes installed for Least Storm-Petrels to the most important breeding area for this species on the island, a place known as "Cerro Colorado." Also, we removed the PVC pipe from these nests and constructed an entrance with rocks. In 2014, egg laying by Leach's Storm-Petrels was verified in two nest boxes: one nest failed (broken egg) and, at the other nest, a chick successfully fledged. Egg laying by Least Storm-Petrels was confirmed at two other nest boxes in 2014; in both cases the egg was deserted. In 2015, the occupancy rate increased, and three nests were occupied by Leach's Storm-Petrels; in all three, a nestling fledged. Also in 2015, five nests were occupied by Least Storm-Petrels; chicks successfully fledged from four of these nests, and in one nest the egg was broken.

The total cost of production of 102 nest boxes, including labor, was around US$800. If the mold does not need to be changed, each additional unit could cost around $7.50. Thus, the production of wood-concrete nest boxes specifically engineered to accommodate each of the three storm-petrel species at San Benito Island West represented an inexpensive alternative compared to the purchase of commercial models available for cavity-nesting passerines. The daily unit production was influenced by weather conditions, as we depended upon the availability of sunlight to let the boxes dry. Also, the mixture was adequate and durable: we recorded fractures on two lids only after four years.

The nest box design and the use of different entrance diameters allowed us to monitor adults and chicks of the two smaller storm-petrel species. We expect occupancy rates to increase over the years. This design and/or methodology could be used at other locations to increase nest site availability for other storm-petrels and seabird species.

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