Chapter 12

Artificial burrows for African penguins on Halifax Island, Namibia: do they improve breeding success?

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On Halifax Island, Namibia, African penguins *Spheniscus demersus* predominantly nest on the surface, where nest contents are susceptible to predation by Kelp gulls *Larus dominicanus*, as well as to heat stress, disturbance and flooding. Penguins also nest under bushes and in abandoned buildings on the island. In addition, some 62 artificial burrows made from plastic rubbish bin halves were set up on Halifax Island between September 2001 and August 2002. Initial occupancy of artificial burrows, in an area where nesting had all but ceased for several decades, was encouraging. Artificial burrows were significantly more successful than surface or building nests. On average, the mean number of fledglings produced per nesting attempt was 0.41 for surface nests, 0.71 for artificial burrows, 0.51 for bush nests and 0.07 for building nests. The higher success of birds breeding in artificial burrows was largely attributable to an exceptionally high survival probability during the chick guard stage. At breeding localities with features similar to Halifax Island, artificial burrows could limit the decline of the species by increasing the availability of suitable nesting habitat and improving breeding success.

Keywords: *Spheniscus demersus*, reproduction, conservation management, nest types, surface nesting

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Introduction

African penguins *Spheniscus demersus* preferentially nest in burrows (Frost et al., 1976a; Siegfried, 1977), but following the removal of guano deposits into which they scraped their burrows, they have been forced to nest on the exposed surface areas (Berry et al., 1974). Exposed nest contents, particularly eggs and small chicks, are vulnerable to predation by Kelp gulls *Larus dominicanus* (Berry et al., 1974; du Toit et al., 2003). Contents of exposed nests are also susceptible to heat stress (Randall, 1983; Williams and Cooper, 1984), flooding (Wilson, 1985) and disturbance (Frost et al., 1976b; du Toit et al., 2003).

Halifax Island (26°37'S, 15°04'E) is situated approximately 200 m off the coast of southern Namibia, near the growing harbour town of Lüderitz. Ambient temperatures there are moderated by strong southerly winds and rarely exceed 25°C throughout the year (Pallett, 1995). Rainstorms are uncommon but can be severe, and flooding of nests may occur in some areas. During the austral winter, hot, dry east winds from the Namib desert occasionally blow, causing air temperatures to rise above 30°C and sometimes leading to mass desertion of nests by penguins (pers. obs).

After vast deposits of superior quality guano had been completely removed from Ichaboe Island, Namibia, by 1846 (Ex-Member of the Committee, 1845), inferior guano deposits were exploited at other seabird islands in the region, including Halifax Island from around 1851 (Kinahan, 1992). Buildings were later erected there to house an island headman charged with protecting guano stocks, as well as teams of labourers, their tools and bagged guano. In 1962, when guano production had declined and harvesting became unprofitable, the last island headman was taken off Halifax Island. The island continued to be scraped every three to four years (Berry et al., 1974; Kolberg, 1992) until the early 1970s (Berry et al., 1974).

Halifax Island consists of a flat, sandy, central plain surrounded by rocky ridges and hills. Burrowing potential is minimal. Several bushes of *Lycium decumbens* grow along ridges on the island; there are scattered, isolated rocky overhangs. These natural features and the few abandoned, disintegrating buildings on the island offer some protection for nesting penguins.

On 14 August 2000, 34 nests containing eggs and 53 nests containing chicks were lost in the space of two hours after air temperatures rose to 37°C in the early afternoon during windless conditions. All lost nests were surface nests and had constituted 18.78% and 37.86% respectively of all active surface nests at the time. The event resulted in the death of 68 chicks (37.16% of all surface nesting chicks), mostly downy, well-fed, and at the post-guard stage. No eggs or chicks were lost in shaded/sheltered nests. This prompted the setting up of artificial burrows as a means to assess the potential benefit of providing additional sheltered nest sites. Here, we investigate the breeding success in different nest types to establish whether artificial burrows would improve breeding success on Halifax Island.

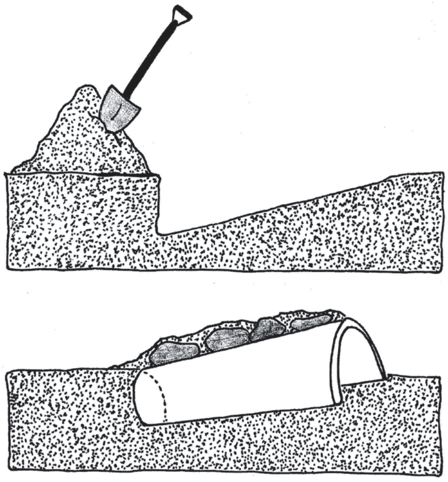

Figure 1: Schematic representation of how artificial burrows made from halved bins were set up on Halifax Island, Namibia. Substrate is excavated at an angle (a) and bin is lowered into excavated area and is covered with rocks and excavated substrate (b)

Methods

The artificial burrows were made from plastic rubbish bins (80 cm in length with a 53 cm diameter opening). Measurements roughly conformed to dimensions of artificial burrows deployed on Marcus Island, South Africa (Wilson and Wilson, 1989) and those used at the East London Aquarium, South Africa (Maritz, 1995). Bins were cut in half lengthwise. In two areas where penguins used to nest before the removal of guano made nesting in the area unattractive, some gravelly ground was excavated for the floor of the burrow. The floor was lined with a layer of guano taken from nearby Ichaboe Island, where guano still accumulates. The bin-halves were then placed as a roof over the guano floor at a slight upward angle and were covered with the excavated gravel and heavy rocks to prevent them from blowing away in strong wind and to provide insulation from the sun (Fig. 1).

All 126 breeding attempts in artificial burrows were monitored. Concurrently, a sample of nests on the surface (101), under bushes (35) and in buildings (30) was monitored. Nests were chosen if they contained eggs which seemed to have been laid recently. Nests were monitored at weekly intervals from early incubation stage, and breeding success was compared for surface-, artificial burrow-, bush-, and building nests. To avoid any potential bias because exact egg-laying dates were generally not known, breeding success was estimated using the Underhill (submitted) extension of the Mayfield method (Mayfield, 1961, 1975); Underhill (submitted) showed that the estimates of probabilities of survival calculated by the Mayfield method were dependent on the choice of time unit and provided an alternative approach based on the exponential distribution that overcomes this problem. As with the Mayfield method, only nests where the outcome was known, and which remained active for longer than two visits, were included in the analysis. Estimates of confidence intervals and rates of daily mortality were compared using standard asymptotic maximum likelihood theory, as described by Underhill (submitted).

On average, eggs hatch two days apart (Williams and Cooper, 1984). We defined incubation time as 40 days per nest and 38 days per individual egg (Randall and Randall, 1981; Williams and Cooper, 1984). Guarded chick stage was defined as 42 days per nest and 40 days per individual chick (Seddon and van Heezik, 1993); post-guarded chick stage was defined as 42 days for nests and individuals, based on the mean chick age at fledging of 82 days in this study. Incubation times for addled eggs were adjusted to be a day longer than maximum incubation time to allow accurate calculations of daily mortality rates.

Table 1: Frequency of breeding attempts by African penguins per artificial burrow between 1 November 2001 and 30 April 2004 on Halifax Island, Namibia

Number of breeding attempts	Number of artificial burrows
0	1
1	17
2	10
3	12
4	12
5	7
6	3

Nest survival probability (i.e. the survival of any contents of the nest, where partial losses are ignored) and individual nest content survival were calculated for the entire nesting period (egg-laying to fledging), defined as lasting 124 days for nests and 120 days for individuals. Since daily mortality rates may differ for different nesting stages (Randall, 1983; Seddon and van Heezik, 1991), survival was also calculated separately for incubation, guarded chick stage and post-guarded chick stage, as well as for the entire chick stage.

Results

Over the study period (2001–2004), peak breeding numbers of African penguins on the island ranged between 500 and 700 pairs of African penguins (Kemper et al., 2007). Of the *c.* 900 recently used nest sites, *c.* 700 were on the surface, with the remaining sites being under bushes (45), in abandoned buildings (85), and under rocky overhangs, in crevices and other man-made structures (70). Most surface-breeding penguins (92%) nested in three distinct colonies on remnant guano patches with a maximum depth of about 30 cm, insufficient to construct a burrow. These provide a relatively soft substrate into which shallow nest bowls are dug. The rest of the surface-breeding birds nest in loose aggregations or solitarily on rocky or sandy substrate. Kelp gulls were present on the island all year round; numbers increased during the austral spring and summer, when between 250 and 350 pairs bred on the island between 2001 and 2004 (Ministry of Fisheries and Marine Resources, Namibia unpubl. data).

Between September 2001 and August 2002, 62 artificial burrows were set up on Halifax Island. The first burrow was occupied by a breeding pair on 7 September 2001, two days after being set up. After this, breeding was attempted in all but one artificial burrow; up to six breeding attempts were recorded for one artificial burrow until the end of April 2004 (Table 1). Breeding attempts in any given artificial burrow were usually but not always by the same pairs. Between five and 33 artificial burrows simultaneously contained either eggs or chicks. Up to nine surface nests, constructed between or against artificial burrows, were active at the same time. In January 2003, 20 adults occupying artificial burrows, of which 15 were breeding at the time, were banded. Of these, one bird subsequently attempted breeding at a neighbouring surface colony. All but three of the banded birds were re-sighted in other artificial burrows but were not necessarily breeding. Each of six banded penguins nested in two different artificial burrows. Seven adult birds, banded before the burrows were set up, attempted breeding in them. Of these, three had not been recorded breeding before and three had previously bred on isolated surface nests in the vicinity of the artificial burrows with mixed success. The other penguin, a female banded as a chick in October 1991, had three previ-

Table 2: Nest and individual breeding stage success of African penguins in different nest types on Halifax Island, Namibia. GS = chick guard stage

	Nest type	n	Hatching success		Surviving GS		Producing fledglings	
			%	n	%	n	%	n
Nest	All	292	58.9	172	39.4	115	33.6	98
	Surface	101	67.3	68	36.6	37	30.7	31
	Burrow	126	57.1	72	49.2	62	42.9	54
	Bush	35	57.1	20	37.1	13	34.3	12
	Building	30	40.0	12	10.0	3	3.4	1
Individual	All	563	50.3	283	32.0	180	26.8	151
	Surface	190	56.8	108	26.3	50	21.6	41
	Burrow	245	50.2	123	42.5	104	36.7	90
	Bush	69	46.4	32	29.0	20	26.1	18
	Building	59	33.9	20	10.2	6	3.4	2

ously recorded unsuccessful breeding attempts in three nest sites in and next to a building, about 50 m from the artificial burrows. One of her nest sites was a sandy burrow against a rock, which collapsed into the burrow and crushed her two small chicks in November 2000. Subsequently she bred three times in one artificial burrow between June 2002 and August 2004 and fledged five large, healthy chicks. She was seen again in May 2005 incubating two eggs on the edge of a surface colony 30 m away from her burrow and 80 m from the building. The nest failed two months later and the penguin was not seen again.

Between 1 November 2001 and 30 April 2004, 422 breeding attempts were monitored, of which 292 were included in the analysis (Table 2). These consisted of 101 surface nests, 126 artificial burrow nests, 35 bush nests and 30 building nests. No heat-related mass desertion events occurred during the study period and no artificial burrows were flooded. The outcome of the remaining 130 breeding attempts was either not known, or the nest did not remain active for more than two visits.

Overall, 92.8% of nests had two-egg clutches, with the remaining 7.2% of nests containing one-egg clutches. The proportion of one-egg and two-egg clutches did not differ between nest types ($\chi^2_3 = 5.5$, $P = 0.14$). Hatching success was highest for surface nests. Most chicks surviving the guard and post-guard stages were from artificial burrow nests (Table 2). In total, 34% of nests produced at least one fledgling, while 27% of eggs survived to fledging. The mean number of fledglings produced per nest was 0.52 overall, 0.41 for surface nests, 0.71 for artificial burrows, 0.51 for bush nests and 0.07 for building nests. The proportion of successful nests producing one or two fledglings differed significantly between nest types ($\chi^2_3 = 31.8$, $P < 0.001$). Building nests were the least successful nest type, with only two chicks fledging from one of 30 monitored nests.

Figs 2 and 3 show survival probabilities for the various breeding stages and nest types. Overall, 54.5% of nests and 47.7% of eggs were expected to survive the incubation period. Survival probability during incubation was lowest for building nests and highest for surface nests, with artificial burrows and bush nests having similar survival probabilities (Fig. 2). Individual incubation success showed a similar pattern between nest types. There were no significant differences in nest or individual incubation success between nest types.

Total expected chick guard stage success was 65.3% for nests and 63.1% for individual chicks. Success for nests and individuals was highest in artificial burrows, followed by bush nests and surface nests, and was lowest in buildings (Table 2, Fig. 2). Survival rates differed significantly between nest types for nests ($\chi^2_3 = 28.25$, $P < 0.001$) and for individuals ($\chi^2_3 = 52.24$, $P < 0.001$). Expected chick post-guard stage success of nests (85.5%) and individual chicks (83.6%) was high overall as well as for all nest types except for building nests (Table 2, Fig. 2). There were no significant differences in post-guard stage daily mortality rates of nests or individuals between nest types.

Nest success for the entire chick stage was highest in artificial burrows, 20.8% higher than in bush nests and 35.0% higher than in surface nests. Building nests fared worst, with an expected chick rearing success of 8.7%. Overall chick survival probabilities differed significantly between nest types for nests ($\chi^2_3 = 32.69$, $P < 0.001$) and for individuals ($\chi^2_3 = 59.32$, $P < 0.001$).

In terms of overall breeding success (from egg-laying to fledging), artificial burrows fared better than bush nests by 11.5%, than surface nests by 12.3%, and than building nests by 31.9%. Breeding success survival probabilities differed significantly between nest types for nests ($\chi^2_3 = 22.50$,

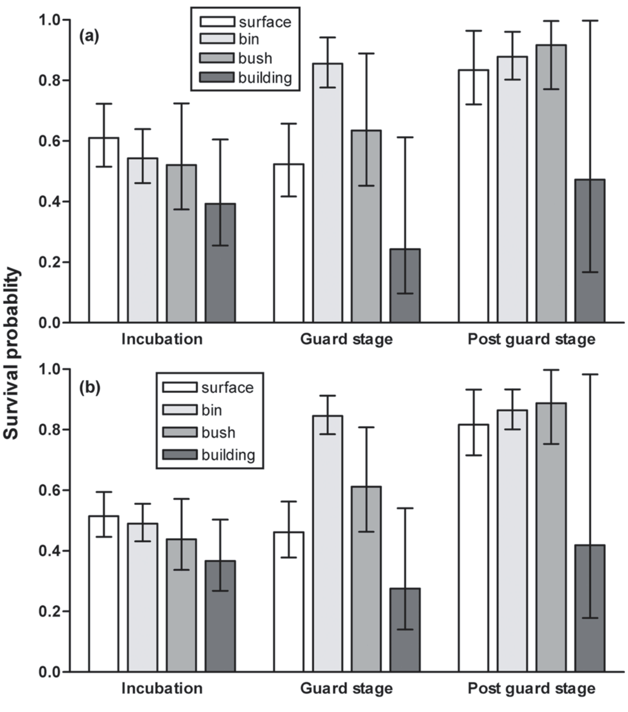

Figure 2: Survival probability of all nest stages (a) per nest and (b) per individual and associated confidence intervals, for different nest types used by African penguins on Halifax Island, Namibia

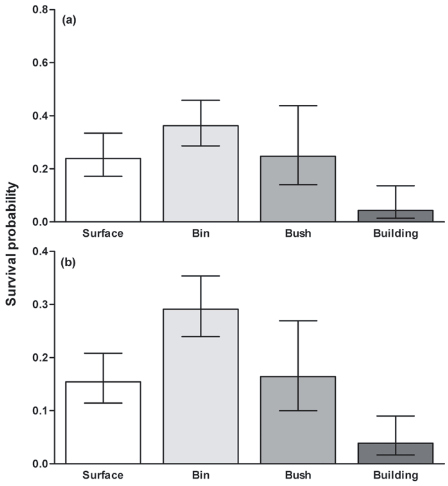

Figure 3: Survival probability over entire breeding attempt (a) per nest and (b) per individual and associated confidence intervals, for different nest types used by African penguins on Halifax Island, Namibia

P < 0.001) and for individuals (χ^2_3 = 38.18, *P* < 0.001).

Discussion

Plastic bin halves were selected for the artificial burrows for a number of reasons. They were readily available, inexpensive and easy to install. They were spacious enough for an adult penguin and two fully-grown chicks. They also offered protection from gulls and provided shade, as well as good drainage. Smooth plastic walls, as opposed to wooden or rough stonewalls, deterred ticks *Ornithodoros capensis* from settling on the burrow wall. Inspections of empty bins did not reveal many ticks inside the burrows, but crevices created by rocks weighing down the bins did attract ticks. The bins proved hardy. They required some maintenance, because penguins tend to use the gravel and rocks weighing down the bins as nesting material. In some cases, burrows became crammed with nesting material (mainly kelp and other seaweed, rocks and shells), making access impossible.

The percentage of successful nests (producing at least one fledged chick) per breeding attempt, as well as the number of chicks fledged per breeding attempt on Halifax Island agreed largely with estimates for African penguin breeding localities in South Africa (Frost et al., 1976a; Randall, 1983; La Cock and Cooper, 1988; Adams et al., 1992; Whittington et al., 1996; Crawford et al., 1999, 2000). Although protected nests were more successful than exposed nests, overall breeding success and that of protected nests was lower than at the other three main penguin breeding localities in Namibia (Kemper et al., submitted). This suggests that breeding success at Halifax Island is under the influence of other factors such as local food availability.

Excluding nests in buildings, nests with cover on Halifax Island had better overall breeding success than exposed nests. This agrees with the findings of Frost et al., (1976a), Cooper (1980) and Seddon and van Heezik (1991), who reported that nesting success in burrows or under rocks was higher than for surface nests on Dassen Island. Murison (1998) compared breeding success of different nest types using the Mayfield method at The Boulders. Overall expected nest success was higher at The Boulders (0.36) than at Halifax Island; at both localities covered nest types (excluding building nests) fared better than surface nests. Covered nests were more successful than exposed nests of Magellanic penguins *S. magellanicus* at Punta Tombo, Argentina (Stokes and Boersma, 1998). At Punta San Juan, Peru, nest burrows of Humboldt penguins *S. humboldti* were more successful than surface nests in areas where burrowing substrate was guano (Paredes and Zavalaga, 2001).

Incubation success was similar for artificial burrows and bush nests, with surface nests more successful during this stage of breeding than the other three nest types. Nest site fidelity and colony fidelity are thought to be high in African penguins (Randall, 1983). This implies that individuals continue using the same nest site even if nest quality is inferior. In that case, it is possible that the artificial burrows were colonised by young, inexperienced pairs. A number of studies have shown that breeding success is lower in young novice breeders than in older, more experienced breeding seabirds (e.g. Dunnet and Ollason, 1978; Pugesek and Diem, 1983; Bradley et al., 1990; Croxall et al., 1992; Chiaradia and Kerry, 1999; Daunt et al., 2001). Although breeding space is not limited at Halifax as a whole, space within the existing main surface breeding colonies is scarce, and high nest densities there possibly force new breeders to explore other areas. Lower incubation success in artificial burrows could be the result of young birds lacking in parental experience. However, nest site fidelity in African penguins may not be as strong as previously assumed and penguins may readily move nest site if the opportunity arises. It is unlikely that the banded bird which bred at several sites and colonies as far as 80 m distant in the space of six years is an exception, and unless the breeding activities of marked individuals are recorded regularly, these shifts probably go undetected. Why this particular penguin eventually moved from a successful nest site to a seemingly inferior nest site is, however, unclear.

The higher success of birds breeding in artificial burrows was largely attributable to a high survival probability during the chick guard stage. Birds nesting under some form of cover are less likely to flee during disturbance by humans or aerial predators and therefore expose their nest contents (Giese et al., submitted, pers. obs). Small chicks are not able to regulate their body temperature (Erasmus and Smith, 1974). Even if a parent flees a protected nest during a disturbance, the chick will be protected from exposure to extreme temperatures at least for a short time. Exposed chicks in protected nests are less easily detected by gulls than surface-nesting chicks (Stokes and Boersma, 1998). Post-guard chick survival was high for all nest types. At this stage chicks are able to thermo-regulate and can defend themselves against gulls if they are reasonably healthy.

At Robben Island, where wooden A-frame structures serve as artificial nests and at Stony Point, where cement boxes were set up, temperatures measured inside artificial nests were much higher than in natural burrows, warmer than in bush nests and similar in temperature to surface nests (J. Griffin, pers. comm.). At Dassen Island, surface nest air temperatures were up to 9.5°C higher than in burrows (Frost et al., 1976a). Temperature was not measured in the Halifax Island study, but penguins occupying artificial burrows appeared less heat-stressed during a hot day than surface-nesting penguins, which would frequently stand up with their flippers stretched out, pant or even abandon nests. This was rarely observed in penguins nesting in burrows.

Artificial nests as a means of improving breeding success have also been used for other penguin species. The Yellow-eyed penguin *Megadyptes antipodes* preferred nest boxes to open sites on grazed grassland which lacked cover (Lalas et al., 1999). At Punta San Juan, Peru, breeding success of Humboldt penguins in artificial (covered) nests was similar to naturally covered nests, and higher than surface nests (Araya et al., 2000). At the Otago Peninsula, New Zealand, breeding success of Little penguins *Eudyptula minor* was generally higher in nest boxes than in burrows (Perriman and Steen, 2000) while at Penguin Island, Australia, breeding success of Little penguins in artificial nest boxes did not differ significantly from that in bushes (Klomp et al., 1991).

Despite offering protection from temperature extremes, flooding and detection of nest contents by gulls, nests inside buildings performed poorly. The building nests monitored during this study were all inside badly lit buildings, where little or no direct sunlight ever reached the nests. At Halifax Island, older chicks in artificial burrows and bush nests usually emerged from their nests in the early mornings or late afternoons to spend some time basking in the sun. This was not the case with chicks in building nests, which spent their entire time in low light. As a result of the lack of sunlight, the buildings on Halifax Island were damp and often infested with fleas and ticks. Chicks in buildings generally appeared to be in poor condition (pers. obs). The effects of poor light conditions are also likely to affect breeding success at the back of the penguin breeding caves at Sylvia Hill (25°08'S, 14°50'E) and Oyster Cliffs (25°20'S, 14°49'E), Namibia, which only benefit from some diffuse late afternoon sunlight. Although Halifax Island is off-limits to the public, illegal landings, mainly by curious tourists, occasionally take place. Buildings housing breeding penguins appear to be the main attraction. This disturbance may lead to increased nest abandonment in buildings. Alternatively, the sample size of building nests may have given rise to Type II errors. Klett and Johnson (1982) suggested that a minimum of 50 nests should be used for comparative purposes when using a Mayfield method approach, and the wide confidence intervals associated with the survival probabilities for bush and building nests indicated a lack of accuracy.

The dataset was not large enough to investigate the effect of nest types on different causes of mortality at Halifax Island. Seasonal differences in breeding success at different nest types, particularly during the Kelp gull breeding season in summer and during hot east wind events in winter, should be investigated.

The initial occupancy of artificial burrows on Halifax Island, in an area where nesting had all but ceased for several decades, has been promising. On Possession Island (27°01'S, 15°12'E), artificial covered nests made of wood and rocks were immediately occupied after construction. However, occupancy dropped rapidly within a year, and finally the structures were not used at all. Closer inspection revealed heavy tick infestations (Y. Chesselet pers. comm.). The success of artificial burrows may therefore be design-dependent and site-specific, and may depend on how long burrows are deployed for if parasite build-up is a factor. At breeding localities with characteristics similar to Halifax Island, these artificial burrow design introduced in this study (provided they are maintained properly) could limit the further decline of the species by increasing the availability of suitable nesting habitat and improving breeding success.

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