Monitoring and Restoration of Ashy Storm-Petrels at Santa Cruz Island, California, in 2007

William R. McIver[1], Harry R. Carter[2] and A. Laurie Harvey[3]

[1] U.S. Fish and Wildlife Service
Arcata Fish and Wildlife Office
1655 Heindon Road
Arcata, California 95521
USA

[2] Carter Biological Consulting
1015 Hampshire Road
Victoria, British Columbia V8S 4S8
Canada

[3] Montrose Settlements Restoration Program
Channel Islands National Park
1901 Spinnaker Drive
Ventura, California 93001
USA

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ABSTRACT

In 2007, Carter Biological Consulting and U.S. Fish and Wildlife Service (Arcata and Ventura Fish and Wildlife Offices) were contracted with funds from the Montrose Settlements Trustee Council to continue gathering baseline data on population size, reproductive success, breeding phenology, and predation; and to develop and test restoration techniques for larger-scale implementation in 2008. Artificial nest site prototypes were deployed at two locations (Cavern Point Cove Caves and Orizaba Rock), to aid in developing restoration strategies in subsequent years. In addition, temperature loggers were placed adjacent to and outside of each artificial site to measure outside ambient temperatures in the vicinity of the artificial site. A total of 83 nests were found in 2007 at four locations where nesting activities were monitored, and reproductive success (proportion of chicks fledged per eggs laid) at these four locations (combined) was 65%. Based on temperature logger data and other information, we recommend (during 2008) the installation of clay roofing tiles as artificial nest sites and the implementation of social attraction techniques at Orizaba Rock, to facilitate use of artificial nest sites by Ashy Storm-Petrels, to prevent or reduce impacts from avian predation or human disturbance.

INTRODUCTION

Endemic to California and northwestern Baja California, Mexico, Ashy Storm-Petrels (*Oceanodroma homochroa*) have a small global population size (*ca*. 10,000 birds) and breed from Mendocino County (*ca*. 39° N) to Todos Santos Islands (*ca.* 32° N) (Ainley 1995; Carter *et al., in press*). The largest known nesting colonies occur at the South Farallon Islands in central California, and at Santa Barbara, Prince, and Santa Cruz Islands in southern California (Ainley *et al.* 1990; Carter *et al*. 1992, *unpubl. data*; Sydeman *et al.* 1998a,b, McIver 2002). Knowledge of population size, breeding biology, and conservation issues of Ashy Storm-Petrels at Santa Cruz Island has increased dramatically since 1991, although nesting was first documented in 1912 (Wright & Synder 1913; Carter *et al.* 1992, 2007). From 1995 to 2002, Humboldt State University implemented standardized monitoring of population size (using nest counts), reproductive success, breeding phenology, and predation at Orizaba Rock, Bat Cave, Cavern Point Cove Caves, Cave of the Birds' Eggs, and Dry Sandy Beach Cave (McIver & Carter 1996; McIver 2002; Carter *et al.* 2007). Subsequent surveys at these locations were performed from 2003 to 2005 by the U.S. Fish and Wildlife Service (Ventura Fish and Wildlife Office) and Carter Biological Consulting (McIver & Carter 2006; Carter *et al.* 2007).

In 2005, the Montrose Settlements Trustee Council identified several seabird restoration concepts to be implemented with funds obtained through litigation over long-term effects of organochlorine pollutants in the Southern California Bight (MSRP 2005). The need for restoration for Ashy Storm-Petrels at Orizaba Rock, Scorpion Rocks, and possibly other locations at Santa Cruz Island was identified based on contaminant-related eggshell thinning and reduced numbers of nest sites at certain locations at Santa Cruz Island (Fry

1994, Kiff 1994; McIver 2002; Carter et al. 1992, 2007, *unpubl. data*; D. Welsh, H. Carter, and W. McIver, *unpubl. data*). In 1991-96, no Ashy Storm-Petrel nests were found at Painted Cave, Scorpion Rocks, and Gull Island where breeding was previously documented (Carter *et al.* 1992, *unpubl. data*). Numbers of nests at Orizaba Rock declined since 1995, possibly due to lights from squid-fishing boats resulting in high avian predation (Carter *et al., in press*). Predation by island spotted skunks (*Spilogale gracilis amphiala*) in 2005 also resulted in decimation of the Bat Cave colony, the largest known colony at Santa Cruz Island (McIver & Carter 2006).

In 2006, Carter Biological Consulting and U.S. Fish and Wildlife Service (Ventura Fish and Wildlife Office) were contracted with funds from the Montrose Settlements Trustee Council to continue nest surveys and monitoring for Ashy Storm-Petrels at five locations at Santa Cruz Island to provide continued baseline data on population size, reproductive success, breeding phenology, and predation for use in restoration assessments (Carter et al. 2007). This baseline information has assisted design of restoration actions and will be used for measuring long-term population changes in response to restoration actions and other natural and anthropogenic factors. Monitoring at Santa Cruz Island also has provided key information on the status of this rare storm-petrel which has declined at Santa Cruz Island and at the South Farallon Islands, but has increased at the Coronado Islands (Sydeman *et al.* 1998b, Carter *et al.* 2006, 2007, *in press*). Prior to 2006, long-term monitoring was focused at the South Farallon Islands (Ainley *et al.* 1990; Ainley 1995; Sydeman *et al.* 1998a). A long-term monitoring program for Ashy Storm-Petrels in the Channel Islands is needed as a long-term goal, where at least half of the world population breeds (Carter *et al.* 1992*, in press*).

In 2007, Carter Biological Consulting and U.S. Fish and Wildlife Service (Arcata and Ventura Fish and Wildlife Offices) were contracted with funds from the Montrose Settlements Trustee Council to continue monitoring work on Ashy Storm-Petrels at Santa Cruz Island for: a) gathering baseline data on population size, reproductive success, breeding phenology, and predation; and b) developing and testing restoration techniques for larger-scale implementation in 2008. In this report, we summarize monitoring and restoration work conducted in 2007.

METHODS

Nest Monitoring

In 2007, we used standardized methods (McIver & Carter 1996, 2006; McIver 2002) to search for and monitor all nests of Ashy Storm-Petrels in accessible habitats at Bat Cave (BC), Cave of the Bird's Eggs (COBE), Cavern Point Cove Caves (CPCC), Dry Sandy Beach Cave (DSBC), and Orizaba Rock (OR). We visited four locations (all except DSBC) on 2-3 June, 10-11 July, 14-15 August, 23 September, and 18 October (Table 1). DSBC was visited only on 15 August. All trips to and accommodations at Santa Cruz Island were conducted aboard the charter boat *Miss Devin*, operated by Ocean Sports

Private Charters. Nesting habitats were accessed from an inflatable boat powered by 15 or 20 h.p. outboard engines which was launched from the *Miss Devin*.

We defined a storm-petrel nest site as a crevice, cavity, or depression containing an adult storm-petrel(s), chick, egg, or numerous eggshell fragments (that together constituted at least one quarter of an egg). We searched for and examined nests with the aid of headlamps, small flashlights, and maps adapted from Bunnell (1988). Each nest was mapped and marked with an individually numbered aluminum tag. We monitored all marked nests on subsequent visits, except when tags could not be relocated. All potential nesting habitat was searched at the 4 study locations until August, after which only marked nests were examined due to shortage of time during weather windows.

Observed numbers of birds, eggs and chicks were recorded for each nest site. Because storm-petrels are sensitive to disturbance at nest sites (Ainley *et al.* 1990), we did not handle adults, incubated eggs, or brooded chicks. We estimated ages of chicks based on their plumage development (McIver & Carter 1996; McIver 2002). Evidence of predation was recorded and broken eggs, carcasses, and feather piles were removed to prevent double-counting. Active nests were defined as having evidence of an egg laid in 2007 (i.e., at least one quarter of a fresh eggshell observed). At some nests, no direct evidence of egg laying was found, although eggs may have disappeared before potential detection.

We estimated breeding phenology for each nest (i.e., timing of initiation, hatching, and fledging) using techniques described in McIver and Carter (1997).

Restoration Technique Development

In June and July 2007, artificial nest site prototypes were deployed at CPCC and OR, to aid in developing restoration strategies in subsequent years. Two designs for artificial nest sites were used: 1) plastic and wood composite lumber (ChoiceDek, Weyerhauser Company, USA), and 2) clay and/or cinder roofing tile (Ventura Roofing Company, Ventura, CA) (Figure 1). In June, three sites were deployed at each location, including two plastic/wood composite material, and one clay and/or cinder roof tile. In July, we deployed four additional tile sites at OR. Inside dimensions of composite sites were ~ 0.12 m^2, with two entrances (~5 cm wide x ~8 cm high) on opposite ends of the site. Rocks were placed at tile entrances to reduce entrance sizes to match those of composite sites. Site entrances were made small enough (see Figure 4.1 in Ainley et al. [1990]) to preclude entry by other crevice-nesting seabirds such as Cassin's Auklets (*Ptychoramphus aleuticus*) and Xantus's Murrelets (*Synthliboramphus hypoleucus*). In June, a temperature logger (iButton model DS-1922L, Embedded Data Systems, Kentucky) was placed within each artificial site, preprogrammed to measure air temperatures inside artificial sites every 20 minutes, beginning at 00:00 h (PDT) on 4 June 2007. In addition, an iButton temperature logger was placed adjacent to and outside of each artificial site (except for one site in CPCC) to measure outside ambient temperatures in the vicinity of the artificial site. Temperature loggers were also placed within 10-20 cm of two occupied natural nest sites (one nest site at CPCC and one nest site at OR) for comparison to artificial nest sites. Thirteen temperature loggers were deployed in June. At CPCC, artificial nest sites were placed as far apart from each other as feasible in this small cave. At OR, two artificial nest sites were placed in the cave on the upper west side of the rock, and one artificial nest site was placed in the lower cave. In July, an iButton temperature logger was placed at each artificial nest site deployed in July at OR and simple "track plates" were placed within some artificial nest sites at CPCC and OR to detect any storm-petrel attendance. Track plates were constructed of contact paper affixed to a piece of square plastic, with the edge of the contact paper closest to the site entrance coated with a light dusting of powdered graphite. In September, all temperature loggers (n = 16) and track plates were removed for data downloading. Artificial nest sites were left in place where they had been deployed.

Data Handling and Statistical Analyses

When a second egg was found in a nest in which a previous (i.e., "first") egg had been laid but failed, we defined the second egg as a "replacement" egg. When only one egg was laid in a nest site, we refer to these as "single" eggs. First, single, and replacement eggs were collectively referred to as "all" eggs. The latest egg laid at a nest site within a breeding season (either single or replacement) was referred to as the "last" egg. Hatching success was defined as the percentage of first or single eggs hatched per egg laid for all sites where egg fate was known. Fledging success was defined as the percentage of chicks fledged (from single or replacement eggs) per chick hatched for all sites where chick fate was determined. Reproductive success was defined as the percentage of active nest sites which fledged a chick from single or replacement eggs. Because it is based upon the percentage of chicks hatched, fledging success is inherently based upon the smallest subset of nests. For hatching success, we excluded nests for which egg fates were not known. For fledging and reproductive success, we excluded nests for which egg or chick fates were not known.

One-way analysis of variance (Hintze 2001) was used to compare mean (± SE) dates of initiation, hatching, and fledging between 2005, 2006, and 2007 and between the 4 study locations. Plots of initiation dates were checked for normality, and tested for equality of variances with Modified-Levene Equal-Variance Test (Hintze 2001). Statistical results were considered significant if $p < 0.05$. Descriptive statistics are presented for initiation, hatching, and fledging dates, for first, single, and replacement eggs. For hatching success, chi-square contingency and heterogeneity tests (Hintze 2001) were used.

RESULTS

Bat Cave

Twenty-eight nests were documented in 2007, with 24 (86%) detected in July and 28 (100%) detected in August. Nests occurred in the main room of the cave and in crevices under boulders outside the main entrance of the cave; however, no nests were found in the in the "slope room," a part of the cave where storm-petrels nested previous to the skunk predation event of 2005. Hatching success of first and single eggs (n = 28) was

68%, fledging success of all eggs (*n* = 19) was 95%, and reproductive success of last eggs (*n* = 27) was 67% (Table 2). Ashy Storm-Petrel footprints were observed in fine sand at the top of the slope in the main room. No evidence of avian, deer mouse (*Peromyscus maniculatus*), or skunk predation was found. No Xantus's Murrelet nests were found. One dead Double-crested Cormorant (*Phalacrocorax auritus*) was found on the cobble beach at the main entrance of the cave on 2 June. On 18 October, we observed a bat in the pool room, which had very long ears and may have been a Townsend's long-eared bat (*Plecotus townsendii*). However, we could not confirm this species identification.

Cave of the Birds' Eggs

Twenty-seven nests were documented in 2007, with 26 (96%) detected in July and 27 (100%) detected in August. Hatching success of first and single eggs (*n* = 27) was 85%, fledging success of all eggs (*n* = 23) was 87%, and reproductive success of last eggs (*n* = 27) was 74% (Table 2). A total of nine Pigeon Guillemot (*Cepphus columba*) nest sites were found. We also found: a) two storm-petrel feather piles on 14 June (one with a detached guillemot head); b) four detached guillemot heads (and one headless carcass) on 12 July; c) 1 guillemot feather pile and carcass on 15 August; and d) one storm-petrel feather pile and one headless guillemot chick (large gawky) carcass on 23 September.

Cavern Point Cove Caves

Fourteen nests were documented in 2007 (7 nests in CPCC #4 and 7 nests in CPCC #5), with 11 (79%) detected in July and 14 (100%) detected in August. Hatching success of first and single eggs (*n* = 14) was 71%, fledging success of all eggs (*n* = 9) was 78%, and reproductive success of last eggs (*n* = 13) was 54% (Table 2). No evidence of predation by deer mice on storm-petrel eggs was noted. Several Barn Owl (*Tyto alba*) pellets were found at the entrance of CPCC #5 on 11 July, and one storm-petrel feather pile and one owl pellet were found in the same area on 23 September. No Xantus's Murrelet nests were found. On 2 June, we observed one bat (presumably Townsend's long-eared) roosting in CPCC #4. On 14 August, we found a nest tag and small rock to which it was attached, atop a rock at the entrance to CPCC #5, indicating that it had been found and moved there by a person exploring the cave.

Dry Sandy Beach Cave

This colony was not monitored on each trip in 2007, but evidence of egg laying (i.e., 3 adults, 29 chicks, 9 eggs, and 2 broken eggshells) was observed in 43 nests on 15 August, similar to other July and August surveys between 1995 and 2006 (McIver 2002; Carter et al. 2007). Reproductive success was not determined at this location in 2007. No storm-petrel feather piles or evidence of predation of deer mice on eggs were noted. On 15 August, other observations included: 1) two Common Ravens (*Corvus corax*) on a cliff outside the cave entrance; 2) approximately 100 juvenile Brandt's Cormorants (*P. penicillatus*) roosting on a cliff outside the cave entrance; and 3) one dead Brandt's Cormorant at the edge of the tidepool.

Orizaba Rock

Fourteen nests were documented in 2007, with 14 (100%) detected in July and 13 (93%) detected in August. Hatching success of first and single eggs (*n* = 14) was 50%, fledging success of all eggs (*n* = 7) was 100%, and reproductive success of last eggs (*n* = 13) was 54% (Table 2). One Cassin's Auklet nest was detected on 14 August, although the abandoned egg had likely been laid in the spring or early summer and not observed on previous visits. Two Black Oystercatcher (*Haemotopus bachmani*) nests (each with two eggs) were found on 2 June. Several storm-petrel eggshells were observed in the lower cave and appeared to have rolled out from nest sites above, but hidden from our view, during and/or after incubation.

Breeding Phenology

Mean initiation dates (± SE) for Santa Cruz Island (i.e., 227 first and single eggs) were not significantly different among years in 2005-07 (F = 1.86, p = 0.16, df = 2) (Table 1.3). Initiation dates ranged from 25 April to 16 September for first and single eggs versus 14 July to 4 September for replacement eggs. Mean initiation dates (± SE) were not significantly different among locations at Santa Cruz Island in 2005-07, all years combined (F = 0.42, p = 0.79, df = 4). Mean hatch dates for chicks from first and single eggs differed significantly among years, being earlier in 2007 than 2005 and 2006 (F = 5.8 , p = 0.003, df = 2) (Kruskal-Wallis Z-values 3.0 and 2.7, respectively) (Table 3). Hatch dates ranged from 8 June to 1 October for first and single eggs versus 9 September to 6 October for replacement eggs. Mean fledging dates also differed significantly among years, being earlier in 2007 than 2005 and 2006 (F = 5.3, p = 0.006, df = 2) (Kruskal-Wallis Z-values 2.6 and 2.9, respectively) (Table 3). Fledging dates ranged from 27 August to 26 November for first and single eggs versus the single value of 23 November for one replacement egg.

Artificial Nest Sites and Temperature Loggers

Storm-petrel tracks were not detected on any track plate within artificial nest sites in 2007. Based on data from the iButton temperature loggers, mean average ambient temperature (± standard deviation) in CPCC was 15.6 ± 0.6°C, ranging from 14.6°C to 17.7°C (Table 1- 4). Mean average ambient temperature at OR was 17.3 ± 1.8°C, ranging from 11.6°C to 29.7°C. Mean average temperature for 3 artificial nest sites in CPCC was 15.5 ± 0.6 °C, ranging from 14.6°C to 16.7°C (Table 4). Mean average temperature for 6 artificial nest sites at OR was 17.4 ± 1.8°C, ranging from 12.1°C to 29.2°C (Table 4).

DISCUSSION

Monitoring reproductive success and breeding phenology

Seabird restoration has focused primarily on improving habitat at breeding colonies to increase numbers of breeding birds and reproductive success (Parker et al. 2007). Reproductive success is a key demographic variable needed for assessing population growth conditions and modeling population changes over time, although variation between years clearly needs to be measured and reasons for variation assessed (Ainley *et al.* 1990, Sydeman *et al.* 1998b, McIver 2002). Breeding phenology also is important for assessing natural factors affecting prey availability and adequacy of survey techniques. We found that a minimum of five monthly trips between June and October were adequate for monitoring reproductive success of Ashy Storm-Petrels at Santa Cruz Island in 2007. Breeding phenology in 2005-07 was protracted, as found in 1995-98 (McIver 2002; Figure 1-3). Most eggs were laid in June, most hatching occurred in late July and early August, and most fledging occurred in early to mid October. Reproductive success at four monitored locations combined in 2007 (i.e., 71% hatching success, 90% fledging success, and 65% of active sites fledging chicks; see Table 2) appeared to be similar to or greater than in 1995-98 (McIver 2002). As in 1995-98, higher reproductive success values occurred at COBE and lower values occurred at CPCC and OR. However, these differences were not significantly different ($\chi^2 = 2.4$, $p = 0.49$, $df = 3$), unlike all years between 1995 and 1998.

While reproductive success in 2007 was generally higher than observed in 1995-98 (see McIver 2002), reproductive success was still lowest at CPCC and OR as also noted in 1995-98, possibly due to differences in predation, habitat quality, and/or exposure to human disturbance. For example, several eggshells were not associated with nest sites when found in the lower cavern at OR in 2007, as also observed in 2006. Some eggshells had rolled out of nest sites (i.e., based on presence of yolk or type of broken egg) located above this cavern floor, which are hidden from view and not monitored. Some eggshells also may have been ejected from nest sites by adults after hatch. Causes for eggs rolling out of nests are not known, but based on the known sensitivity of storm-petrels to disturbance, eggs may have rolled out of nest sites if storm-petrels were disturbed during incubation by avian predators (e.g., gulls, ravens, owls) or humans. Fragile nesting substrates at OR also may facilitate such egg losses.

Predation

Western Gulls (*Larus occidentalis*) are known predators of Ashy Storm-Petrels at Southeast Farallon Island (Ainley et al. 1990, Sydeman et al. 1998a). McIver (2002) reported that Barn Owls were predators of Ashy Storm-Petrels at Santa Cruz Island, especially at BC, CPCC, and OR, and that Common Ravens may prey on storm-petrel adults, eggs, and chicks at Santa Cruz Island. Common Ravens probably feed most often on the ground, but can catch birds in flight (Boarman and Heinrich 1999). Often working in pairs, they can pull adult birds off nests to eat eggs or kill adults (Thayer et al. 1998, Boarman and Heinrich 1999). McIver (2002) reported apparent raven predation of a Pigeon Guillemot chick in COBE in July 1997. In June, July, and August 2007, several Pigeon Guillemot carcasses and detached heads, including a large gawky guillemot chick, at COBE, suggested that Common Ravens prey on guillemot adults and chicks in or near nests. Ravens also could prey on Ashy Storm-Petrel adults and chicks in or near nests at COBE. Some storm-petrel feather piles have been found in COBE but ravens also may take smaller carcasses outside COBE for plucking and eating. Pigeon Guillemots are active standing and vocalizing on the surface of the nesting area, on the water in front of the cave, and flying in and out of the cave during the day. These activities may attract ravens to COBE and make guillemots more vulnerable to raven predation than storm-petrels. Emms and Verbeek (1991) reported that Northwestern Crows (*Corvus caurinus*) intercepted Pigeon Guillemots as they flew to the nest with fish to feed their young.

Ravens are ubiquitous at Santa Cruz Island and have been seen roosting or in flight near all monitored Ashy Storm-Petrel nesting locations during the 2005-07 period. Common Ravens also exhibit a commensal relationship with humans and have adapted to human behaviors and human food sources (Boarman et al. 2006). It is possible that ravens may visit storm-petrel breeding locations subsequent to our visitations; if so, our monitoring could make Ashy Storm-Petrels more vulnerable to predation by ravens. However, in 2007, we did not observe evidence of raven predation, such as broken eggs and/or dead chicks and adults outside of nest sites. In addition, Ashy Storm-Petrels are nocturnal in their arrival to and departure from nests sites, and chicks younger than fledging age (~80 d) are generally non-vocal and inactive within their nesting crevices during the day. Therefore, we do not think that ravens prey on large numbers of eggs, chicks, or adults or pose a substantial threat to Ashy Storm-Petrels nesting at Santa Cruz Island.

Compared to 1995-98, relatively low levels of storm-petrel predation (i.e., few carcasses or feather piles) appeared to occur in 2007, as also noted in 2006 (Carter et al. 2007). However, lower numbers of breeding birds also occurred at BC and OR. More work is needed to summarize and assess past predation data for comparison to 2005-07 data. At BC, Barn Owls may have switched to hunting elsewhere, due to the reduction in population size of storm-petrels after the skunk predation event in 2005. Further monitoring of predation will assist in determining trends in the frequency and type of predation upon storm-petrels.

Human Visitation

Evidence of human visitation (unrelated to researcher visitation) was found at CPCC on 14 August when a nest tag was found conspicuously placed atop a boulder at the entrance of one of these caves. In a previous year, this tag had been placed several meters further inside this cave to mark a nest site. A person exploring the cave between the July and August 2007 trips must have removed it and placed it on the boulder. High water occasionally washes caves at Santa Cruz Island and can dislodge some tags, but this usually occurs only during winter storm events. Afterwards, some tags are either not found, are partially buried in sand, or are moved around inside caves. However, they cannot be washed onto the tops of boulders. This event highlights the need for further education of tourists visiting Santa Cruz Island, regarding the susceptibility of storm-petrels and other crevice-nesting seabirds to disturbance. Nesting habitats within the sea caves and on OR are fragile and prone to movement or collapse if carelessly stepped upon. During the breeding season (April-November), storm-petrel adults, chicks, and eggs within nest sites also are vulnerable to being crushed by unaware human visitors.

Artificial Nest Sites and Temperature Loggers

From early June to late September 2007, a wider range of temperatures was found in sheltered areas out of the sun at OR than in CPCC. At CPCC, ambient temperatures varied by about 3.1°C, compared to 18.1°C at OR. Despite the greater range of temperatures at OR, little difference in mean temperatures was evident between artificial nest sites and the natural rock crevice.

Based on examination of track plates, no evidence of storm-petrel visitation of artificial nest sites was found. However, most artificial nest sites had been deployed for about a month before track plates were deployed in some sites. Ashy Storm-Petrels may have: 1) visited artificial nest sites where track plates were not deployed without egg laying; 2) visited artificial nest sites before track plates were deployed in July; or 3) visited the immediate vicinities of artificial sites without entering sites. A lack of visitation of all artificial nest sites was most likely and may have resulted because: 1) most or all natural nest sites with incubating and pre-laying birds were well established prior to deployment of artificial sites in June-July; 2) only small numbers of subadults may have been searching for new nest sites in June-September; and 3) insufficient stimuli (e.g., presence or vocalizing of a potential mate) may have been present to encourage storm-petrels to enter artificial nest sites. Little is known about what factors influence storm-petrels to enter potential natural or artificial nest sites. The process of obtaining a mate and selecting a nest site may require several years.

Restoration Recommendations

Based on the pilot studies described above, we recommend implementation of the following procedures during restoration work proposed for 2008:

Artificial Nest Sites

- Utilize clay roofing tile for artificial nest sites only to minimize cost (see Figure 2);
- Deploy at least 15 tile sites at CPCC, and at least 20 tile sites at OR;
- At each tile site, supply a relatively thick layer (~2 cm depth) of fine gravel (purchased from a garden supply store) to ensure suitable, level, floor substrate for the site (see Figure 2);
- At each tile site, supply a thin layer (~ 1 cm depth) of ultra-fine sand (purchased from a garden supply store) at each nest entrance, and immediately around the outside perimeter of the site. As long as wind does not remove this sand, storm-petrel footprints should be left in the sand, if storm-petrel visitation occurs near artificial nest sites (see Figure 2).

Social Attraction

- Attach a mirror to one outside side wall of the tile site (facing away from ambient light) for half of tile sites (see Figure 2) and not in the remainder at each study location. In other seabird restoration projects, mirrors have been used to attract diurnal seabirds (e.g., Common Murres *Uria aalge* [Parker et al. 2007]) to a certain part of the nesting area where they interact with their own reflection and spend more time at this place. The greater the amount of time that a bird spends at that place: a) the more likely that a second bird will arrive and begin interactions, potentially leading to courtship behavior and breeding, with the first bird at this location; and b) the greater the likelihood of return by the bird with or without interaction with another bird. For nocturnal Ashy Storm-Petrels, although much lower light levels are involved, a mirror located adjacent to a tile site may help attract and retain a visiting storm-petrel near the artificial nest site at night for some time. The greater the amount of time spent in the vicinity of the tile site, the greater the possibility of the storm-petrel entering the tile site with or without a potential mate. Orientation of mirrors away from ambient light sources may encourage birds to move around to the more protected back side of artificial sites (thereby causing more inspection of the artificial site itself) and prevent unwanted attraction to mirrors by potential predators during the day and night.

- In each nest box, insert a small (~ 50 cm^2) cotton bag containing ~20 Ashy Storm-Petrel feathers (previously gathered from feather piles found at Santa Cruz Island) to provide storm-petrel odor at the nest site, to increase stimuli for encouraging storm-petrels to visit, stay near, or enter the tile site (see Figure 2).
- Deploy an Ashy Storm-Petrel vocalization broadcast system near artificial nest sites on OR to attract Ashy Storm-Petrels to portions of OR with artificial nest sites in the upper passageway and lower cave areas. Broadcast equipment would include: a) a compact disc player or iPod; b) pre-recorded vocalizations; c) marine batteries; d) photovoltaic cells; e) timer; f) speakers; and g) protective housing. Vocalization broadcast systems have been successfully used to attract seabirds and restore colonies of Common Murres, Atlantic Puffins (*Fratercula arctica*), Dark-rumped Petrels (*Pterodroma phaeopygia*), and various terns (Kress 1983, Kress and Nettleship 1988, Podolsky and Kress 1992, Parker et al. 2007).

Long-term restoration and monitoring concepts

At OR and CPCC, restoration actions will involve installing artificial nest sites for Ashy Storm-Petrels that will be used for nesting, to prevent or reduce impacts from avian predation or human disturbance. In late March 2008, we propose to install 50 additional artificial nest sites (25 at OR and 25 in CPCC). The nesting habitat improvement efforts at OR will be augmented with a social attraction system. As planned for the Cassin's Auklet restoration project on SBI (A.L. Harvey, *personal communication*), an audio system for broadcasting vocalizations of Ashy Storm-Petrels will be installed at OR. This system was developed in part by the National Audubon Society and has been used successfully for several species, notably by the U.S. Fish and Wildlife Service and collaborators at Devil's Slide Rock, California, for the Common Murre restoration project, funded by the Apex Houston Trustee Council (Parker et al. 2007). Social attraction also has been found to be successful with Leach's Storm-Petrels (*O. leucorhoa*; Podolosky and Kress 1989). The broadcast system should attract Ashy Storm-Petrels to a specific area of OR to encourage use of artificial nest sites placed there. Like other storm-petrels, Ashy Storm-Petrels are highly philopatric, and immature, non-breeding birds are known to prospect for nest sites (James-Veitch 1970, Ainley 1995). Therefore, we expect that most birds will not leave established nest sites on other parts of the rock and that instead birds that breed in artificial sites near the broadcast system will either have previously nested in this area or will be first-time breeders from this or other colonies that are in the process of finding a mate and nest site. Vocalizations will be played nightly during the pre-breeding season (starting in March-April) and during part of the egg laying period (May-June or May-July) to aid in attraction of prospecting birds. Installation of artificial nest sites and the broadcast system will occur prior to the breeding season.

A similar broadcast system may be employed at BC in 2009. Ashy Storm-Petrels have not nested in the "Slope Room" since the skunk predation event of 2005. Much suitable nesting habitat exists (about 20-30 nests per year in 1995-2004; W.R. McIver and H.R.

Carter, *unpubl. data*) but insufficient stimuli currently exist to repopulate this major portion of the nesting habitat at BC. Restoration efforts would likely facilitate re-colonization of this important nesting area.

Baseline data on population size, reproductive success, and breeding phenology at Santa Cruz Island have been gathered only in 1995-98 (McIver 2002) and 2005-07 (McIver and Carter 2006; Carter et al. 2007; this study). Implementation of most restoration actions is anticipated in 2008. Continued monitoring should be conducted in 2009-11 at a minimum to gather 3 years of post-restoration data for assessing immediate responses to restoration actions and to check and modify restoration actions as needed. Additional studies of storm-petrel response to restoration techniques may be required to refine restoration actions in 2009-10. A sample of eggs also will be collected and archived between 2008 and 2010 for eventual examination of eggshell thinning and pollutant levels for comparison to samples collected in 1992-97.

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Table 1. Field trips conducted in 2007 for Ashy Storm-Petrel nest monitoring and restoration at Santa Cruz Island, California.

Trip Number	Field Dates	Locations[1]	Field Staff	Support Vessel
Trip 2007-01	2-3 June	BC, COBE, CPCC, OR	B. McIver H. Carter A. Harvey P. Hébert	*Miss Devin*
Trip 2007-02	10-11 July	BC, COBE, CPCC, OR	B. McIver C. Hamilton D. Cooper J. Turner	*Miss Devin*
Trip 2007-03	14-15 August	BC, COBE, CPCC, DSBC, OR	B. McIver H. Carter P. Hébert P. Martin	*Miss Devin*
Trip 2007-04	23 September	BC, COBE, CPCC, OR	B. McIver A. Harvey C. Hamilton L. Baker	*Miss Devin*
Trip 2007-05	18 October	BC, COBE, CPCC, OR	B. McIver H. Carter P. Henderson	*Miss Devin*

[1] Abbreviations: BC (Bat Cave); COBE (Cave of the Birds' Eggs); CPCC (Cavern Point Cove Caves); DSBC (Dry Sandy Beach Cave); and OR (Orizaba Rock).

Table 2. Hatching, fledging, and reproductive success of 83 Ashy Storm-Petrel nests monitored at Santa Cruz Island, California, in 2007. Locations are coded: Bat Cave (BC); Cave of the Bird's Eggs (COBE); Cavern Point Cove Caves (CPCC), and Orizaba Rock (OR). Clutches are coded: 1, first and single; and 2, replacement. Sample sizes are in parentheses.

		Location				
	Clutch	BC	COBE	CPCC	OR	Total
Hatching Success	1	68% (28)	85% (27)	71% (14)	50% (14)	71% (83)
	2	25% (4)	0% (1)	--	--	20% (5)
Fledging Success	All	95% (19)	87% (23)	78% (9)	100% (7)	90% (58)
Reproductive Success	Last	67% (27)	74% (27)	54% (13)	54% (13)	65% (80)

Table 3. Timing of breeding (mean ± standard error in days) for Ashy Storm-Petrels at Santa Cruz Island, California during 2005-07. Sample sizes of nests used for phenology are shown in parentheses.

Year	Clutch	Initiation	Hatch	Fledging
2005	1	14 June ± 2.6 d (81)	26 July ± 2.6 d (55)	8 Oct. ± 2.5 d (44)
	2	5 Aug. ± 10.6 d (3)	22 Sep. ± 13.5 d (2)	--
2006	1	11 June ± 3.0 d (61)	22 July ± 2.8 d (50)	8 Oct. ± 2.6 d (40)
	2	14 July (1)	--	--
2007	1	7 June ± 2.6 d (85)	14 July ± 2.6 d (59)	29 Sep. ± 2.3 d (53)
	2	17 Aug. ± 7.5 d (6)	17 Sep.	--
2005-07	1	10 June ± 1.6 d (227)	20 July ± 1.6 d (164)	4 Oct. ± 1.5 d (137)
	2	10 Aug. ± 6.2 d (10)	21 Sep. ± 8.0 d (3)	--

Table 4. Descriptive statistics for 16 iButton temperature loggers at Cavern Point Cove Cave #4 (CPCC) and Orizaba Rock (OR), Santa Cruz Island, California, from 4 June to 22 September 2007.

			Temperature Data (°C)					
iButton	Location	Nest Type or Outside of Nest	Mean	Standard Deviation	Range	Minimum	Maximum	Count
1	CPCC	Open	15.60	0.60	3.01	14.66	17.67	7992
2	CPCC	Open	15.46	0.61	1.5	14.65	16.15	7992
3	CPCC	Artificial (composite)	15.68	0.64	2.00	14.70	16.71	7992
4	CPCC	Artificial (tile)	15.42	0.63	1.50	14.59	16.09	7992
5	CPCC	Artificial (composite)	15.46	0.64	1.50	14.69	16.20	7992
6	CPCC	Outside of Nest	15.76	0.44	1.00	15.20	16.20	7992
7	OR	Artificial (composite)	17.07	1.66	11.52	13.14	24.66	7992
8	OR	Outside of Nest	17.02	1.73	13.02	13.13	26.15	7992
9	OR	Rock crevice	17.01	1.65	12.02	12.68	24.70	7992
10	OR	Artificial (composite)	17.22	2.11	17.02	12.10	29.12	7992
11	OR	Outside of Nest	17.22	2.12	17.53	12.17	29.70	7992
12	OR	Artificial (tile)	17.17	1.82	13.52	12.19	25.71	7992
13	OR	Outside of Nest	17.22	1.78	16.52	11.64	28.16	7954
14	OR	Artificial (tile)	17.64	1.66	14.52	13.65	28.17	5220
15	OR	Artificial (tile)	18.03	1.70	15.02	14.20	29.22	5220
16	OR	Artificial (tile)	18.01	1.22	9.51	15.13	24.64	5220

(a)

(b)

Figure 1. Prototypes of artificial nest sites deployed at Orizaba Rock, Santa Cruz Island, California, in 2007: (a) plastic/wood composite material (photo by Percy Hébert); and (b) cinder (left) and clay (right) roof tile materials with track plates inside (photo by Bill McIver).

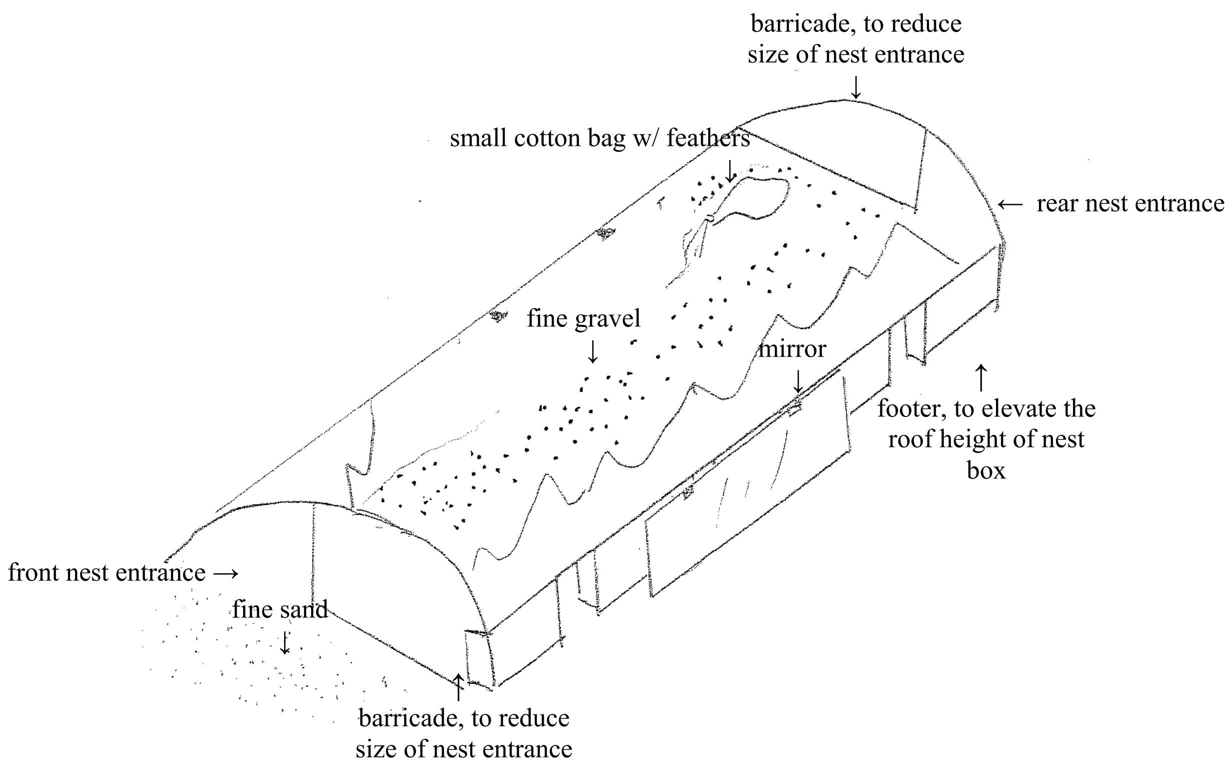

Figure 2. Artificial clay tile nest site to be deployed at Orizaba Rock in 2008. In this sketch, the roof of the nest box is not shown, so that features inside the nest box can be seen.