Monitoring and Restoration of Ashy Storm-Petrels at Santa Cruz Island, California, in 2010

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ABSTRACT

In 2010, the U.S. Fish and Wildlife Service (Arcata Fish and Wildlife Office), Channel Islands National Park, Carter Biological Consulting, and Simon Fraser University were funded by the Montrose Trustee Council to continue implementation of restoration actions and continue gathering population and reproductive data on Ashy Storm-Petrels (*Oceanodroma homochroa*) at Santa Cruz Island, California. Social attraction using vocalization broadcast was redeployed at Orizaba Rock, as done in 2008-09. Continued increase in colony size at Orizaba Rock occurred with a total of 29 egg-laying sites documented in 2010 (i.e., 23 natural and 6 artificial). However, reproduction or attendance was apparently affected at many artificial sites by Common Ravens (*Corvus corax*), which dismantled artificial nest sites and may have depredated at least one adult Ashy Storm-Petrel. Significant modifications to the design of artificial nest sites are needed to prevent future raven impacts. Future monitoring will determine whether impacts by ravens in 2010 have affected the overall degree of success of restoration efforts on Orizaba Rock over time. However, overall reproductive success at Orizaba Rock in 2010 was not lower than reference colonies. At four sea caves and Orizaba Rock, a total of 126 nests (including natural crevices and artificial sites) were found and monitored in 2010 which had a combined reproductive success (i.e., proportion of egg-laying sites that fledged chicks, including five sites with replacement eggs laid) of 67%, relatively high compared to baseline (i.e., years 1995-97) data. As in 2009, nesting did not occur in 2010 at Cavern Point Cove Caves, following an unusual heavy predation event by island spotted skunks (*Spilogale gracilis amphiala*) in 2008. Traps were redeployed in 2010 at Bat Cave, Cave of the Birds' Eggs, and Cavern Point Cove Caves to prevent further predation of storm-petrels by skunks, but no skunks were detected in these sea caves in 2010. Future monitoring also will determine if and when the colony at Bat Cave fully recovers from the major skunk predation event of 2005. NPS signs were first deployed at Orizaba Rock in 2010 to prevent or reduce unauthorized human access, following earlier placement of NPS or TNC signs at sea caves in 2009. A pilot study also was conducted to develop a camera system for documenting and describing Ashy Storm-Petrel behaviors at Orizaba Rock and Bat Cave. Extensive video footage (i.e., 240 hours) was recorded with 3 cameras from April to October and archived. Preliminary examination of video footage showed strong responses by storm-petrels to vocalization broadcasts and storm-petrels were recorded entering and attending several artificial nest sites near the speakers. Ashy Storm-Petrel behaviors were described and compiled into an ethogram to aid future analyses.

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.* 2008a). 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, McIver *et al*. 2009b). Although nesting was first documented at Santa Cruz Island in 1912, knowledge of population size and distribution of Ashy Storm-Petrels at Santa Cruz Island increased dramatically during 1991-96 surveys by Humboldt State University (HSU) (Wright and Snyder

1913; Carter *et al.* 1992, 2007, *unpubl. data*). From 1995 to 2002, HSU also implemented standardized monitoring of population size (using nest counts), reproductive success, breeding phenology, and predation at five locations at Santa Cruz Island, including Orizaba Rock, Bat Cave, Cavern Point Cove Caves, Cave of the Birds' Eggs, and Dry Sandy Beach Cave (McIver and Carter 1996; McIver 2002; Carter *et al.* 2007). In 2003-05, the U.S. Fish and Wildlife Service (USFWS) (Ventura Fish and Wildlife Office) and Carter Biological Consulting (CBC) continued monitoring at these locations (McIver and Carter 2006; Carter *et al.* 2007).

In 2002-05, the Montrose Trustee Council identified several seabird restoration concepts for implementation with funds obtained through litigation over long-term effects of organochlorine pollutants to wildlife (especially raptors and seabirds) in the Southern California Bight (Montrose Settlements Restoration Program 2005). The need for restoration of Ashy Storm-Petrels at Santa Cruz Island was identified based on: a) apparent loss of small colonies (i.e., no nests were found during 1991-96 surveys) at Painted Cave, Scorpion Rocks, and Gull Island where breeding had been previously documented (Carter *et al.* 1992, 2007, *unpubl. data*); b) DDE-related eggshell thinning from eggs collected at Santa Cruz Island in 1992, 1996 and 1997 (Fry 1994; Kiff 1994; Carter *et al.* 2008b); c) reduced numbers of nest sites at Orizaba Rock after 1996 possibly due to lights from squid-fishing boats resulting in high avian predation (McIver 2002; Carter *et al.* 2008a); and d) decimation of the Bat Cave colony, the largest known colony at Santa Cruz Island, due to an unusual predation event by island spotted skunks (*Spilogale gracilis amphiala*) in 2005 (McIver and Carter 2006; Carter *et al.* 2008a).

In 2006, CBC and USFWS (Ventura Fish and Wildlife Office) were funded by the Montrose Trustee Council to continue nest surveys and monitoring for Ashy Storm-Petrels at five locations at Santa Cruz Island to provide pre-restoration baseline data on population size, reproductive success, breeding phenology, and predation for developing a long-term monitoring program for restoration assessment (Carter *et al.* 2007). This baseline information has assisted design of restoration actions and is being 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, 2008a). Prior to 2006, long-term monitoring of Ashy Storm-Petrels was focused at Southeast Farallon Island (Ainley *et al.* 1990; Ainley 1995; Sydeman *et al.* 1998a). A long-term monitoring program for Ashy Storm-Petrels in the Channel Islands, where at least half of the world population of Ashy Storm-Petrels breeds, also is a long-term goal for Channel Islands National Park (CINP) and other state and federal agencies (Carter *et al.* 1992, 2008a).

In 2007, CBC, USFWS (Arcata and Ventura Fish and Wildlife Offices), and CINP were funded by the Montrose 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 (McIver *et al.* 2008).

In October 2007, the Center for Biological Diversity petitioned the Secretary of the Interior and USFWS to list the Ashy Storm-Petrel as threatened or endangered under the Endangered Species

Act of 1973 (hereafter "Act"). In response to this petition, a 90-day finding was published in May 2008 (USFWS 2008) that stated that listing under the Act may be warranted with initiation of a status review. The status review was published in August 2009 (USFWS 2009), stating that listing the Ashy Storm-Petrel under the Act was not warranted at that time.

In 2008-09, USFWS (Arcata Fish and Wildlife Office), CINP, and CBC were funded by the Montrose Trustee Council to: a) continue monitoring work to gather data on population size, reproductive success, breeding phenology, and predation of Ashy Storm-Petrels at Orizaba Rock and four sea caves at Santa Cruz Island; b) continue social attraction (i.e., vocalization broadcasting) and further deployment of artificial nests at Orizaba Rock; c) deploy skunk traps in sea caves to prevent or reduce further predation of Ashy Storm-Petrels by island spotted skunks (2009 only); and d) deploy signs at sea caves to prevent or reduce unauthorized human access (2009 only).

In 2010, USFWS (Arcata Fish and Wildlife Office), CINP, CBC, and Simon Fraser University (SFU) were funded by the Montrose Trustee Council to continue the restoration and monitoring activities as conducted in 2008-09 and in addition to: a) evaluate Ashy Storm-Petrel nocturnal behaviors in relation to social attraction techniques; b) evaluate future recruitment and visitation of Ashy Storm-Petrels by initiating a chick PIT-tag banding project; c) evaluate storm-petrel visitation to and attendance of artificial nest sites using temperature loggers; d) deploy signs at Orizaba Rock to prevent or reduce unauthorized human access; and e) conduct additional surveys at other breeding colonies at Santa Cruz Island.

In this report, we summarize restoration and monitoring of Ashy Storm-Petrels at Santa Cruz Island in 2010.

METHODS

Nest Monitoring

Most egg laying at Santa Cruz Island does not begin until May or June (McIver 2002). In February-May 2010, previously-marked nest sites of Ashy Storm-Petrels were monitored at Bat Cave (BC), Cave of the Bird's Eggs (CBE), Cavern Point Cove Caves (CPC; comprised of two adjacent caves, Cave #4 and Cave #5), and Orizaba Rock (OR) (Table 1; Figure 1). An exception to this occurred at OR, where all nests (previously-marked and newly-found) were monitored beginning in February 2010. Each location, when visited, was visited for 1-5 hours during each monthly field trip on 23 February, 12 March, 14-15 April, and 12-13 May. Colony visits at this time of the year in 2010 were related mainly to planning and implementation of behavior work for filming and recording vocalizations. Limited nest monitoring was conducted to provide information on numbers of active nests (i.e., with eggs) during the earliest parts of the breeding season.

In June-August 2010, all nests (previously-marked and newly-found) were monitored using standardized methods on monthly field trips involving complete searches of accessible habitats at BC, CBE, CPC, and OR for new nests (see McIver and Carter 1996, 2006; McIver 2002). Each location was visited for 1-5 hours during each monthly field trip on 14-15 June, 12-13 July, and

12-13 August. Dry Sandy Beach Cave (DSB) was not checked in June and July to prevent possible impacts to nesting Brandt's Cormorants (*Phalacrocorax penicillatus*) at the cave entrance; but standardized monitoring occurred in August.

Laying of first and replacement eggs ceases in August (McIver 2002); therefore, it is not necessary to search for new nests after August. In September-December 2010, still-active nests (i.e., with chicks on the last check) were monitored at BC, CBE, DSB, and OR. On 15-16 September and 12 October, BC, CBE, DSB and OR were monitored. In 16 November, only OR was monitored. On 2 December, only DSB was monitored. Late season trips were needed to determine fledging success for many nests, due to later breeding in 2010 (see later).

All field trips to and accommodations at Santa Cruz Island were provided aboard the charter boat *Miss Devin*, operated by Ocean Sports Private Charters (Santa Barbara, California). Nesting habitats were accessed from an inflatable boat powered by a 15 or 20 horsepower outboard engine launched from the support vessel.

A storm-petrel nest was defined as a crevice, cavity, or depression containing definite evidence of egg laying (i.e., a whole egg, numerous eggshell fragments [i.e., at least one quarter of an egg which was considered sufficient to ensure that it represented a new egg and did not represent leftover fragments of an earlier egg in the same year or from previous years], or a chick). At some previously tagged nest sites, no direct evidence of egg laying was found, although a few eggs may have disappeared before our detection. We searched for and examined nests with the aid of headlamps, small flashlights, and maps adapted from Bunnell (1988). Each nest or suspected nest (i.e., in some cases, an adult in incubating position was present and presence of an egg could not be directly detected) was mapped and marked with an individually numbered aluminum or plastic tag. All birds, eggs and chicks were recorded for each marked nest on each visit. Because storm-petrels can be sensitive to disturbance at nest sites (Ainley *et al.* 1990), we did not handle adults, incubated eggs, or brooded chicks. Approximate ages of chicks were later estimated based on their plumage development (McIver and Carter 1996; McIver 2002). Evidence of predation was recorded and broken eggs, carcasses, and feather piles were removed to facilitate detection of replacement eggs and prevent double counting.

Approximate breeding phenology was estimated for each nest (i.e., timing of initiation [egg-laying], hatching, and fledging) using methods described in McIver and Carter (1997). In 2006-10, we have updated these methods and will report them in a separate report (McIver *et al*., in prep).

Social Attraction and Artificial Nest Sites

Artificial nest sites and social attraction equipment first were deployed at OR in 2008 (McIver *et al.* 2009a). A single vocalization broadcast system was used that had been developed previously by the National Audubon Society and has been used widely for social attraction purposes (e.g., Parker *et al.* 2007). The vocalization broadcast equipment in the tote box was wired to one speaker, which was left in place after 2008 in the Upper West Cavern on OR.

Table 1. Field trips conducted in 2010 for Ashy Storm-Petrel monitoring and restoration at Santa Cruz Island, California. All field trips conducted on support vessel *Miss Devin*.

Field Dates	**Locations**[1]	**Field Staff**	**Main Activities**
23 February	OR	Harvey, Halpin, Martin	Develop plan for filming in caverns, monitor marked sites
12 March	OR	Harvey, Auer, Barnes	Deploy artificial nest sites, monitor marked sites
14-16 April	BC, CBE, CPC, DR, OR	McIver, Harvey, Carter, Halpin, Hamilton, Clock	Monitor marked sites, deploy broadcast vocalizations at OR, restoration check, deploy infrared cameras, initiate behavior filming, deploy songmeters, deploy traps, deploy signs, mist netting
11-13 May	BC, CBE, CPC, OR	McIver, Carter, Halpin, Hébert, Lee	Monitor marked sites, restoration check, behavior filming, deploy traps
14-16 June	BC, CBE, CPC, OR	McIver, Harvey, Carter, Halpin, Pereksta	Nest monitoring, restoration check, behavior filming, trap check
12-13 July	BC, CBE, CPC, OR	Harvey, Carter, Halpin, Cooper, Turner	Nest monitoring, restoration check, behavior filming, trap check
12-13 August	BC, CBE, CPC, DSB, OR	McIver, Harvey, H. Carter, Halpin, K. Carter, Mazurkiewicz	Nest monitoring, restoration check, behavior filming, trap check, remove broadcast system
15-16 September	BC, CBE, CPC, DSB, OR	McIver, Harvey, Mazurkiewicz, Falxa, Little	Nest monitoring, behavior filming, trap check, remove traps at CPC, deploy Reconyx camera
12 October	BC, CBE, DSB, OR	McIver, Harvey, Carter, McMorran	Monitor sites with chicks, camera check, remove traps at BC and CBE, remove infrared cameras at OR, remove songmeters from BC and CBE
17 November	OR	Harvey, Mazurkiewicz, Auer, Barnes	Monitor late sites with chicks, remove card from Reconyx camera
2 December	DSB	Harvey, Carter, Mazurkiewicz	Monitor late sites with chicks

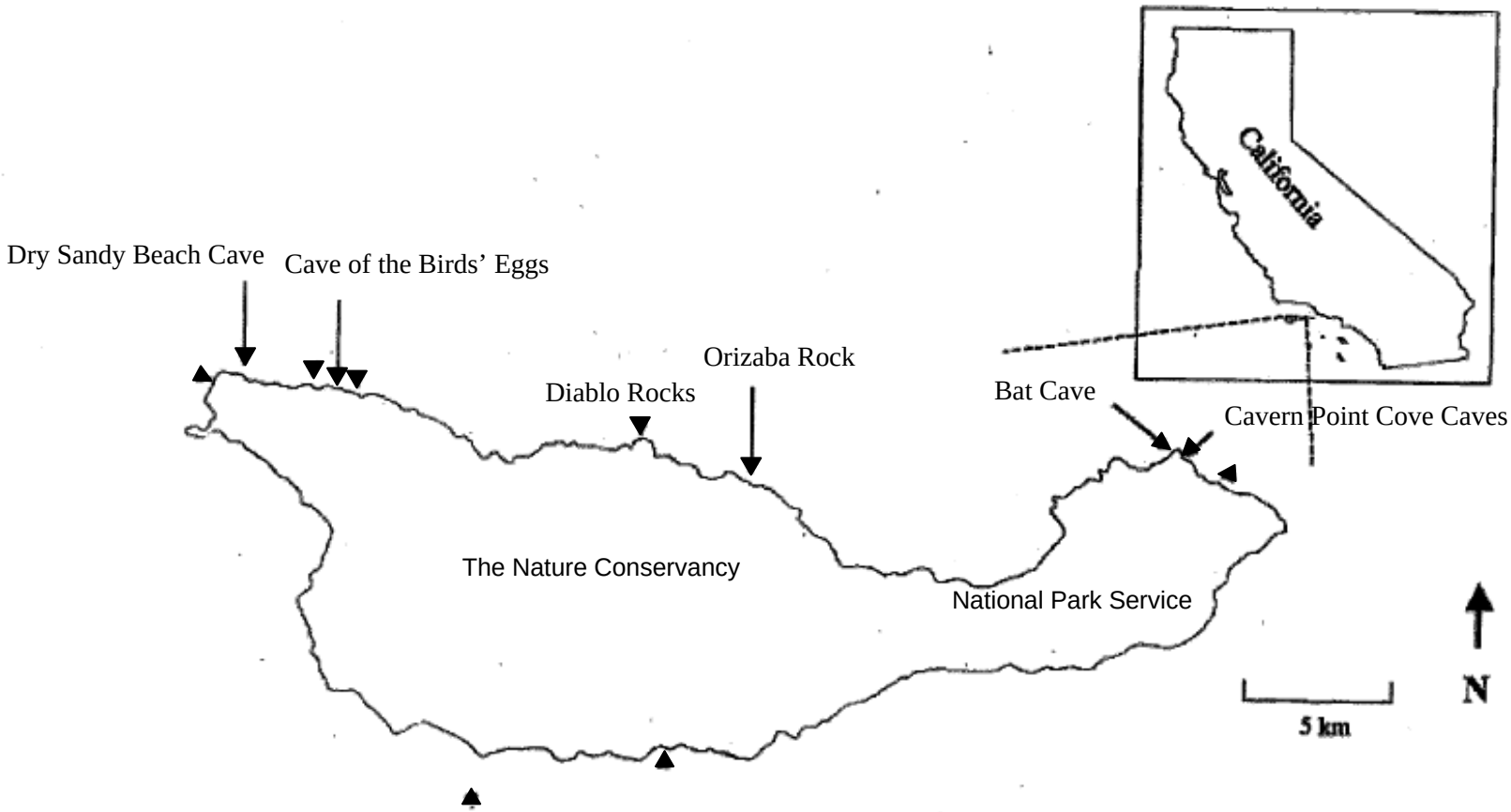

Figure 1. Breeding locations of Ashy Storm-Petrels at Santa Cruz Island, California. All known breeding locations are indicated by triangles. Locations studied in 2010 also are named (see text).

In 2008-09, 26 artificial nest sites (21 artificial sites in 2008 and 5 artificial sites in 2009) were deployed at OR in the Upper West Cavern and Upper East Cavern within 1-7 m of the speaker to encourage storm-petrels originally attracted to vocalization broadcasts to then spend time in or near adjacent artificial site areas. In 2010, an additional 4 artificial sites were deployed in the Upper West Cavern, for a total of 30 artificial nest sites deployed at OR. As in 2008, each additional artificial nest site was housed under a single concave cement roofing tile (A.L.L. Roofing and Building Materials Corporation, Ventura, California) that was 36 cm long, 20 cm wide, and 18 cm high (all inside dimensions) and each provided sufficient space for a single Ashy Storm-Petrel nest. Heat-sterilized (to prevent non-native introductions) fine pumice gravel (depth 2-3 cm) was spread under each tile to form a suitable floor for each nest site. Rocks were placed at tile entrances to reduce entrance sizes to generally match those of natural sites and prevent access by avian predators. Site entrances also were small enough to prevent entry by other crevice-nesting seabirds such as Cassin's Auklets (*Ptychoramphus aleuticus*) which also nest at OR in small numbers. One end of each tile was blocked completely by rocks or pieces of cement tile backer boards to provide an enclosed site that mimicked a natural nest crevice and protected the interior of the site from wind. Fine sand was placed around artificial nest sites in an attempt to detect storm-petrel footprints that would indicate site visitation by storm-petrels. At some artificial sites, additional sand was placed at the bottom edges of tiles to reduce wind inside sites. All materials brought to sites were thoroughly checked or cleaned to prevent non-native introductions.

Evaluation of Efficacy of Social Attraction

In 2010, we began a two-year study to gather information to assist evaluation of the efficacy of vocalization broadcasting in attracting Ashy Storm-Petrels (Halpin 2010; see Appendix A). In the first year (2010), we conducted a pilot study with limited funds that focused on developing: (1) methods of gathering video footage of Ashy Storm-Petrels; and (2) an ethogram or catalog of Ashy Storm-Petrel behaviors through preliminary examination of footage obtained at a restoration site and a natural site plus available knowledge from the literature. In the second year (2011), we plan to gather data using an experimental design with broadcast vocalizations turned off for short periods, such that we can compare frequencies and types of behaviors with and without broadcast vocalizations.

In April through October 2010, two automated infrared video camera systems were deployed in separate caverns at OR ("Upper West Cavern" and "Lower Cavern"), and one camera was deployed at BC. Each camera system consisted of a main housing unit built into a large Pelican case containing a digital video recorder (MDVR25; Supercircuits, Austin, Texas), a 12v lead acid battery and a power supply timer unit (see Appendix A for more details). The housing units contained the bulk of the recording equipment. A small infrared security camera (Supercircuits PC168 IR Camera) and a weatherproof microphone (Supercircuits ETS SM1-W) were attached to concealed cables leading back to the unit. This allowed for minimal disturbance to birds by storing the bulk of the recording equipment away from filming areas used frequently by storm-petrels. Cameras were mounted on wooden blocks and affixed to the walls of the lower cavern and upper west cavern at OR. At BC a camera was mounted to a tripod and secured firmly in place for the duration of the breeding season. Each camera recorded for 4 hours each night between 22:30 h to 02:30 h. Camera deployments were made within a few days of the new moon

each month and data were collected for several days before the battery power became too low for operation. Cameras recorded the same area at each colony for each deployment from April through August 2010. Video data were examined to ensure image quality for analyses and to describe types of behavior and responses to social attraction and artificial nest sites. Behavioral types were documented in an ethogram to allow for future quantification of behaviors and hypothesis testing of Ashy Storm-Petrel responses to social attraction and artificial nests.

To supplement descriptions of Ashy Storm-Petrel behaviors, we also deployed automated acoustic monitoring devices (Songmeter-2, Wildlife Acoustics Inc., Concord, Massachusetts) in BC and CBE from April through September 2010 to record Ashy Storm-Petrel vocal activity each night (see Appendix A for more details). Devices were set to record for 1 minute in every 10 minutes from 18:00 to 06:00 h the following day with a single 4-hour recording between 23:00 h and 03:00 h. Each device was placed central to each colony and at least one foot above the ground to minimize sound distortion. Monophonic recordings were made at 22050 hz. Devices were serviced once each month when batteries were changed and data downloaded. Copies of raw data were archived at SFU and CINP.

Recruitment Study

At present, most recruitment to OR and sea cave colonies is likely derived from locally-fledged chicks, although also possibly involving a few birds hatched at other colonies. To better understand how the OR colony and sea cave colonies are sustaining themselves over the long term, passive integrated transponder (PIT) technology was used to examine future recruitment of Ashy Storm-Petrels at artificial and natural sites at OR, and at natural sites in sea caves. PIT-tags (Model TX1400ST; Biomark, Inc., Boise, Idaho), are durable microchips that return a unique ID and a time/date stamp when in range of an appropriate antenna. PIT-tags were incorporated into bands that were attached to chicks. Following methods described in Zangmeister *et al*. (2009), each tag was encased in a length of 1.6 mm diameter electrical shrink tubing that was slightly longer than the length of the tag (~1.2 cm) and attached to two plastic black bands (size XCSD Darvic; Avinet Inc., Dryden, New York; Figure 2) at the edge of the tubing. The shrink tubing was then heated and a small amount of quick-drying glue was applied to secure the PIT-tag/shrink tubing assembly to the plastic bands. One PIT-tag band was attached to either the left or right tarsus of each accessible chick and the unique electronic tag identification number was read with a scanner (APR350 Reader, Agrident GmbH, Barsinghausen, Germany) and written on the corresponding nest monitoring data form. Each handled chick (with the exception of seven chicks handled only in August 2010) was also banded with a uniquely-numbered stainless steel/aluminum U.S. Geological Survey band (size 1B). Immediately after banding, each chick was returned to its nest site.

Protection from Predation by Island Spotted Skunks

As in 2009 (see McIver *et al*. 2010), lethal “body-grip” skunk traps (model 220 Conibear trap, Oneida Victor Inc. Ltd., Euclid, Ohio) were set inside protective wooden boxes (approximate box dimensions: 19 cm x 19 cm x 50 cm) and deployed at BC, CBE, and CPC in 2010. After deployment, trap boxes were examined on each field trip in 2010 to detect any trapped skunks,

Figure 2. Materials (Darvic plastic bands, shrink tubing, 12 mm PIT-tag) used to assemble PIT-tag bands, an assembled PIT-tag band (see arrow in photo), and a banding spoon (used to attach PIT-tag bands to Ashy Storm-Petrel chicks), used to study future visitation and recruitment of Ashy Storm-Petrels at Santa Cruz Island, California, in 2010.

ensure proper functioning of traps and boxes, and to replace bait. Traps, protective boxes, and bait were removed from the sea caves during September and October field trips.

Artificial Nest Site Visitation by Storm-Petrels

In 2010, temperature loggers (iButton model #1922L, Embedded Data Systems, Lawrenceburg, Kentucky) were placed in 30 artificial nest sites and in the open in the upper caverns at OR to evaluate visitation and attendance of artificial nest sites by Ashy Storm-Petrels. A small Velcro strip was glued to each iButton, which allowed the iButton to be attached to and removed from a long and thin prod, inserted into each artificial nest site (Figure 3). In addition, four iButtons were similarly attached to four small pieces of backer board, placed in the upper caverns (outside of and near artificial nest sites) to measure ambient temperatures in the caverns. Each iButton was accurate to within 0.9° F.

Alteration of Artificial Nest Sites

A reconnaissance camera (model HC500 Hyperfire, RECONYX Inc., Holmen, Wisconsin) was deployed in the "Upper East Cavern" at OR on 15 September, to attempt to capture images of corvids and/or human vandals altering artificial nest sites there (Figure 4).

Figure 3. Temperature logger (iButton model 1922L; see arrow in photo) and assembled wand, to which an iButton was affixed (with velcro) and then inserted into artificial nest sites, to monitor attendance and visitation of Ashy Storm-Petrels at Orizaba Rock in 2010.

Figure 4. Remote motion sensing camera (RECONYX model HC500 Hyperfire) deployed in "Upper East Cavern" at Orizaba Rock on 15 September 2010.

Human Visitation

Signs prohibiting the entry of sea caves by tourists were deployed at four locations (BC, CPC, CBE, and DSB) in 2009 (McIver *et al*. 2010). These signs were refurbished, as needed, in 2010. A sign prohibiting visitation by tourists was first deployed at OR in September 2010.

Additional Surveys

To augment knowledge of population size and trends of Ashy Storm-Petrels at other nesting locations at Santa Cruz Island, we planned to conduct the following surveys in 2010 when possible with time and conditions available during scheduled trips for nest monitoring:

- mist-net captures on Diablo Rocks in April, May, June, July and August;
- nest searches at Diablo Rocks and Shipwreck Cave in July or August; and
- nest searches and mist-net captures at Gull Island in October.

Nest Monitoring Data Handling and Descriptive Statistics

When a "second" or "third" egg was found in the same nest site where an egg (i.e., "first") had been laid earlier but failed, we considered such second and third eggs to be "replacement" eggs by the same breeding pair. Due to monthly nest checks and inexact information on when the first egg failed, we could not determine how much time had elapsed after failure of the first egg to ensure sufficient time (i.e., likely 1-2 weeks) for formation of the replacement egg. When only one egg was laid in a nest site in a breeding season, we referred to it as a "single" egg. If another egg was found in the same nest site where an egg had been laid and successfully fledged a chick, we considered this egg as a single or first egg laid by a second breeding pair. For some analyses, single, first, second, or third eggs were treated as independent events and collectively referred to as "all" eggs. For most analyses, we examined annual breeding effort for each breeding pair, using either single/first eggs or "last" eggs). Hatching success was defined as the percentage of single/first eggs hatched per egg laid for each breeding pair where egg fate was known. Fledging success was defined as the percentage of last chicks fledged per last chick hatched for each breeding pair where chick fate was determined. Reproductive success was defined as the percentage of breeding pairs which fledged a last chick. Since it is based upon hatched chicks, fledging success has the smallest sample size of breeding pairs. For hatching, fledging, and reproductive success, we excluded a few breeding pairs for which egg or chick fates were not known. Descriptive statistics for breeding phenology (i.e., timing) for laying, hatching and fledging are presented for single/first eggs versus replacement eggs for each breeding pair. Descriptive statistics for breeding performance (i.e., success) are presented for each breeding pair for: a) hatching (single/first versus replacement eggs); and b) fledging and chicks per breeding pair (last eggs). Methods for determining breeding phenology and hatching, fledging, and reproductive success of Ashy Storm-Petrels are described in McIver and Carter (1996, 1997) and McIver et al. (2010, in prep.).

RESULTS

Breeding Phenology

Mean dates of egg laying, chick hatching and chick fledging in natural and artificial nest sites at each monitored location at Santa Cruz Island are summarized in Table 2. In 2010, estimated average laying dates in natural crevices (all locations combined) ranged from 3 March to 21 September for single/first eggs (*n* = 130) versus 24 May to 15 September for replacement eggs (*n* = 7). Laying dates for artificial nest sites at OR ranged from 7 March to 29 July (*n* = 6 single eggs). Hatch dates in natural crevices (all locations combined) ranged from 8 June to 17 November for single/first eggs (*n* = 98) versus 20 July to 22 September for replacement eggs (*n* = 4). Hatch dates in artificial nest sites at OR ranged from 27 April to 29 June (*n* = 4 single eggs). Fledging dates for natural crevices (all locations combined) ranged from 27 August to 25 December for chicks from single/first eggs (*n* = 81), versus 8 October to 16 December for chicks from replacement eggs (*n* = 2). Fledging dates for artificial sites at OR ranged from 14 September to 16 September for chicks from single eggs (*n* = 2). Dates of laying and hatch at DSB were about two months later than at BC, CBE, and OR (natural sites only). On 2 December, two nests at DSB contained chicks that were too young to determine fledging status. Assuming average chick growth, these chicks would have fledged between 15 December 2010 to 26 January 2011. If growth was slower than average, these chicks may have fledged as late as February 2011.

Bat Cave

Ashy Storm-Petrel: Sixty nests were documented at BC in 2010. Most nests (*n* = 51) occurred in the "main room," and nesting (*n* = 1) in a passageway leading to the "pool room" was documented for the first time since 1998. Hatching, fledging and reproductive success were 85% (*n* = 60), 90% (*n* = 50), and 79% (*n* = 56), respectively (Table 3). Storm-petrel footprints were observed in fine sand at: a) the top of the front slope in the main room; b) at the top of the large slope in the slope room; and c) at the top of the slope outside the cave (near tag #746). On 14 April, an infrared camera was deployed in the main room near storm-petrel nests occurring among driftwood. Data from the camera were downloaded monthly until October, when we removed the camera.

Predation: Three skunk traps were deployed 14 April and removed 12 October, and no evidence that skunks (or any other spp.) entered trap boxes was found. A pellet, likely regurgitated from a Barn Owl (*Tyto alba*), was found in the main room on 14 April; contents included two storm-petrel skulls, and storm-petrel bones and feathers. In addition, a large streak of bird guano was detected on 14 April on a boulder near the main entrance to the cave, and was likely deposited by a Barn Owl or a Common Raven (*Corvus corax*). No evidence of deer mouse (*Peromyscus maniculatus santacruzae*) scavenging/predation or skunk predation was found in 2010.

Xantus's Murrelet: On 14 April 2010, one Xantus's Murrelet nest was found (but not marked) in a crevice along the base of the cave wall at the top of the slope in the main room. One hatched eggshell fragment from an egg that appeared to have been laid in 2010 was found in a crevice.

Table 2. Average timing of breeding (mean date ± standard error in days) for Ashy Storm-Petrels at five locations at Santa Cruz Island, California, in 2010. Sample sizes of eggs used for phenology calculations are shown in parentheses. Location abbreviations are in Table 1. Clutch codes: 1, single and first eggs combined; 2, replacement eggs.

Location	Clutch	Initiation	Hatch	Fledging
BC	1	1 June ± 3 (58)	14 July ± 3 (51)	1 October ± 3 (45)
	2	13 August ± 16 (3)	10 September (2)	-
CBE	1	5 June ± 5 (21)	15 July ± 6 (14)	8 October ± 6 (13)
DSB	1	5 August ± 3 (29)	21 September ± 4 (19)	12 December ± 6 (11)
CPC	1	0	0	0
OR[a]	1	4 June ± 8 (22)	21 July ± 9 (13)	9 October ± 11 (11)
	2	11 July ± 25 (4)	21 August ± 32 (2)	12 November ± 35 (2)
OR[b]	1	18 May ± 19 (6)	12 June ± 15 (4)	15 September ± 1 (2)
All[a]	1	17 June ± 3 (130)	30 July ± 4 (97)	13 October ± 4 (80)
	2	25 July ± 16 (7)	31 August ± 14 (4)	12 November ± 35 (2)

[a] Natural crevices only; [b] Artificial sites only.

Table 3. Percent hatching, fledging, and reproductive success of Ashy Storm-Petrel nests monitored at Santa Cruz Island, California, in 2010. Location abbreviations are in Table 1. Eggs are coded: 1, first and single; 2, replacement; and last. Sample sizes in parentheses.

		Location							
	Egg	BC	CBE	CPC	DSB	OR[a]	OR[b]	All[a]	All[b]
Hatching Success	1	85.0 (60)	71.4 (21)	0 (0)	65.5 (29)	54.5 (22)	57.1 (28)	73.5 (132)	73.2 (138)
	2	100 (2)	-	-	-	75.0 (4)	75.0 (4)	83.3 (6)	83.3 (6)
Fledging Success	Last	91.7 (48)	86.7 (15)	0 (0)	91.7 (12)	92.9 (14)	83.3 (18)	91.0 (89)	89.2 (93)
Reproductive Success	Last	78.6 (56)	61.9 (21)	0 (0)	50.0 (22)	61.9 (21)	55.6 (27)	67.5 (120)	65.9 (126)

[a] Natural nest sites only; [b] Natural and artificial nest sites.

Brandt's Cormorant: On 13 May, two adult Brandt's Cormorants were observed attending a nest on a cliff ledge adjacent to and about 50 m northwest of the cave entrance. On 15 June, two Brandt's Cormorant nests were observed on the cliff: a) nest #1— one adult stand on nest and one adult sit in nest; and b) nest #2— one adult stand on nest, two chicks, and one adult flew from nest.

Human Disturbance: CINP signs prohibiting cave entry by tourists, which had been deployed inside both the main room and slope room in 2009, were intact and in their original locations (i.e., unaffected by ocean wave action or human vandalism). No evidence of human disturbance or non-researcher human visitation was detected in 2010. However, large numbers of kayakers were seen in waters off the entrance to this cave on several occasions.

Evaluation of Storm-Petrel Nocturnal Behaviors: Between April and August 2010, 85.5 hours of video footage on 23 nights were collected at BC. About 50% of this footage was reviewed for image quality and for describing breeding behavior by Ashy Storm-Petrels (see Orizaba Rock). To describe behaviors, multiple reviews of video segments with behaviors were performed to ensure proper interpretation and description of activities. However, in most cases, image quality was not sufficient to produce representative still images.

Extensive driftwood habitat at BC made it difficult to view as much storm-petrel activity as at OR because storm-petrels spent much time moving to their nests beneath the driftwood. Overall activity appeared to be less at BC than OR. Due to driftwood habitat, more widely dispersed nest sites and the camera field of view, it was difficult to view the full extent of behavior types at this colony and location within the colony. In Appendix B, certain nesting behaviors observed at BC captured from video footage are included (Figures B-4, B-5).

Evaluation of Storm-Petrel Vocalizations: Approximately 4 hours and 48 minutes of acoustic data were recorded each night at BC. This resulted in approximately 72 hours of acoustic recordings per month.

Cave of the Birds' Eggs

Ashy Storm-Petrel: Twenty-one nests were documented at CBE in 2010. Hatching, fledging, and reproductive success were 71% (n = 21), 87% (n = 15), and 65% (n = 20), respectively (Table 3).

Predation: One skunk trap was deployed on 15 April and removed 12 October, and no evidence that skunks (or seabirds) entered trap boxes was found. No evidence of avian or skunk predation nor mouse scavenging/predation was found in 2010.

Pigeon Guillemot: Adult Pigeon Guillemots (*Cepphus columba*) were recorded (i.e., sitting on the water within the cove adjacent to the cave entrance, flying out of the cave, or perched on the rock at the cave entrance) as follows: a) 15 April — 16 adults on water, 1 adult flew out of cave; b) 12 May — 4 adults on water, 4 adults flew out, and 5 adults perched; c) 14 June — 32 adults (5 holding fish) on water; and d) 12 July — 20 adults flushed from water at cave entrance. Twenty-one nests (*i.e.*, evidence of egg laying) were documented in 2010; 16 nests hatched at

least one egg and 7 nests appeared to fledge at least one chick (i.e., ≥ "small gawky chick" and no carcass found; Table 4). No adult or chick carcasses were found away from nest sites.

Human Disturbance: No evidence of human disturbance or non-researcher human visitation was detected in 2010. Signs were deployed here in 2009-10.

Wave Wash Events: On our first visit on 15 April, the TNC sign prohibiting cave entry by tourists, which had been deployed in 2009, was found adjacent to the north cave wall, apparently moved by winter wave action. The sign was battered but still legible, and was redeployed near its original location. In addition, two dead adult Ashy Storm-Petrels with wet plumage were found in the cave away from suitable nest sites and pools of water were observed in several low-lying places in the cave. These storm-petrels had likely been sitting in crevices and were killed by a large wave(s) that entered the cave. Based on the amount of mold and maggots on the carcasses, the carcasses were likely lying in the cave for about 3-10 weeks; hence, they probably were killed in February-March 2010. On 12 May, the TNC sign was again knocked over (likely by a wave) but was still near its April redeployed position. In addition, several Ashy Storm-Petrel sites were observed to have been physically modified; boulders had moved or sediment had shifted, altering nesting crevices and nest sites occurring under cave walls. These sites may have been altered by earlier winter wave action, but were only noted as altered in May.

Other Species: Two nests of Pelagic Cormorant (*Phalacrocorax pelagicus*) were observed on a cliff adjacent to the cave on 14 June; no behaviors or numbers of adults or chicks were provided. One bat (species not identified) was observed in the back of the cave on 15 September. Although we did not note specific dates, Peregrine Falcons (*Falco peregrinus*) were commonly observed soaring near the cave and adjacent cliffs in 2010.

Evaluation of Storm-Petrel Vocalizations: Approximately 4 hours and 48 minutes of acoustic data were recorded each night at CBE. This resulted in approximately 72 hours of acoustic recordings per month.

Cavern Point Cove Caves

Ashy Storm-Petrel: No nests were documented in Cave #4 or Cave #5 in 2010.

Predation: Three skunk traps were deployed 14 April and removed 16 September, and no evidence that skunks (or other spp.) entered trap boxes was found. No evidence of avian or skunk predation nor mouse scavenging/predation was found in 2010.

Human Disturbance: No evidence of human disturbance or non-researcher human visitation was detected. CINP signs originally installed in 2009 remained intact.

Xantus's Murrelet: No nests were found in 2010.

Bats: Bats with long ears and tawny and gray colored fur were observed, as follows: a) 13 May — 12 bats flying inside Cave #5 and 1 bat flying in Cave #5; and b) 13 August — one dead bat was found in the secondary entrance to Cave #5, which was subsequently identified by USGS as

Table 4. Nesting activities[1] of Pigeon Guillemots at Cave of the Birds' Eggs in 2010.

Nest Number	15 Apr	12 May	14 Jun	12 Jul	12 Aug	15 Sep	Clutch Size	Hatch	Fledge
"A"	-	2E	2MDC	1MFC	0	0	2	2	1
"A1"	-	-	1SDC+1EFh	1LDC	0	0	1	1	Unk
"B"	-	2SDC	1LDC+1SDCdd	0	0	0	2	2	Unk
"B1"	-	-	-	2E	2LDC	0	2	2	Unk
"C"	-	2E	2MGC	0	0	0	2	2	2
"D"	-	1E	1E	1E	0	0	1	0	0
"E"	-	1E	1LD-SGC	ND	0	0	1	1	1
"AA"	1B/2E	2SDC	2FFC	0	0	0	2	2	2
"BB"	-	1E	1E	1Ebk-coll	0	0	1	0	0
"CC"	-	1E	1SGC	EF-coll	0	0	1	1	1
"DD"	-	-	1E	1DC	1SDCdd	0	1	1	0
"EE"	-	-	1Ebk	1Ebk-coll	0	0	1	0	0
"FF"	-	-	1B	2MFC	0	0	2	2	2
"GG	-	-	1SDC+1EFh	1E	1Ebk	0	2	1	Unk
"HH"	-	-	1E	1SDC	1MFC	0	1	1	1
"II"	-	-	-	2E	ND	0	2	Unk	Unk
tag #737B	-	1E	2LDC	0	0	0	2	2	Unk
tag #765	-	-	1EFh	1EFh	0	0	1	1	0
tag #821	-	-	2LDC	0	0	0	2	2	Unk
tag #839	-	-	1E+1EFh	1E+1EFh	0	0	2	1	0
tag #840	-	½ EF	0	0	0	0	1	Unk	Unk
tag #900A	1B	0	0	0	0	0	ND	ND	ND

[1] Abbreviations: B = adult bird, -coll = collected, dd = dead, E = egg only, Ebk = broken egg, EF = eggshell fragment, FFC = fully-feathered chick, LDC = large downy chick, LGC = large gawky chick, MDC = medium downy chick, MFC = mostly feathered chick, ND = no data, SDC = small downy chick, SGC = small gawky chick, 0 = empty nest.

an adult male Townsend's big-eared bat (*Corynorhinus townsendii;* National Wildlife Health Center case #23240).

Dry Sandy Beach Cave

Ashy Storm-Petrel: Twenty-nine nests were documented in 2010. Hatching, fledging and reproductive success were 65% (*n* = 29), 92% (*n* = 12), and 50% (*n* = 22), respectively (Table 3).

Predation: On 12 August, one abandoned Pigeon Guillemot egg was found in the open and away from suitable nesting habitat, possibly moved by a deer mouse. Two Ashy Storm-Petrel eggshell fragments were found in the open and away from suitable nesting habitat, possibly depredated or scavenged by deer mice or moved by storm-petrels after hatch. No evidence of avian or skunk predation was found in 2010.

Human Disturbance: No evidence of human disturbance or visitation was observed. The TNC sign that had been deployed on the beach in 2009 was missing at the time of the first survey and apparently was washed away by waves during the winter. The sign was not replaced in 2010.

Pigeon Guillemot: Two nests were found on 12 August; one nest contained a medium gawky chick, and one nest contained two eggs. One adult was noted on the water outside the cave entrance on 12 August. More guillemots may have bred earlier in the season in the cave and their nesting activity went unobserved.

California sea lion: Approximately 10 California sea lions (*Zalophus californianus*) were observed at the beach of the cave on 2 December 2010.

Orizaba Rock

Ashy Storm-Petrel Restoration: On 14 April, the vocalization broadcast system was redeployed and activated, and 4 new artificial nest sites were added to 26 pre-existing artificial nest sites (total = 30). The additional artificial nest sites were installed on the northeastern portion of the ledge in the Upper West Cavern. Data from the video cameras were downloaded monthly until October, when the 2 cameras were removed from OR.

During each field trip in May to August 2010, vocalization broadcast equipment was tested and determined to be functioning properly. We are confident that Ashy Storm-Petrel vocalizations were broadcasted nightly from 14 April to 11 August. On 12 August, the solar panel and broadcast equipment were removed, but the speaker in the Upper Cavern was left in place. Similarly, all artificial nest sites were left in place.

Ashy Storm-Petrel Nest Monitoring: Including 22 natural and 6 artificial sites, 31 nests were documented at OR in 2010, although hatching success was determined only at 28 nests (Table 2). For natural sites, hatching, fledging, and reproductive success were 55% (*n* = 22), 93% (*n* = 14), and 62% (*n* = 21), respectively (Table 3). For active artificial nest sites, hatching, fledging, and reproductive success were 67% (*n* = 6), 50% (*n* = 4), and 33% (*n* = 6), respectively. For all sites (natural and artificial sites combined), hatching, fledging, and reproductive were 57% (*n* = 28),

83% (n = 18), and 56% (n = 27), respectively (Table 3). Three of 6 artificial sites used in 2010 were also used in 2008 and 2009 (tags #A-853B, #A-868, A-869). All six sites used in 2010 also had been used in 2009. Two sites used in 2009 (tags #A-869 and #A-1000) were not used in 2010, although the former was visited in 2010. One other site (tag #A-870) was visited only in 2010.

Ashy Storm-Petrel Breeding Phenology: Unusual early (within season) egglaying by Ashy Storm-Petrels was observed at OR in 2010. On 23 February, two natural sites (newly-found #S-223 and previously-found #701) were each observed to contain one Ashy Storm-Petrel egg. At site #S-223, the egg was described as possibly old (*i.e.*, laid during previous season) but "clean" in appearance; this egg was not seen in March and this site could not be found and was not followed subsequently. At site #701, a storm-petrel egg and a Cassin's Auklet adult were observed in the crevice. For each of these sites, an early initiation date could not be estimated based on nest observations; however, in each site an Ashy Storm-Petrel egg was laid as late as 23 February. On 12 March, one newly-found natural site (#S-317), two previously-found natural sites (#701 and #831) and one artificial site (#A-868) were each observed to contain one Ashy Storm-Petrel egg. Site #S-317 was newly-found on 12 March, but it is not known whether this site was checked and found empty on 23 February; consequently, an early initiation date for this site cannot be determined based on nest observations. At site #701, a Cassin's Auklet adult was again observed in the crevice, but auklet nesting activity was not subsequently observed, and storm-petrel activity was not observed again until July 2010. At site #831, the egg could have been laid as early as 23 February or as late as 12 March. Specific estimated average laying dates of single eggs for artificial sites were: 7 March (#A-868), 13 May (#A-863), 15 May (#A-859), 16 May (#A-847), 29 May (#A-853B) and 29 July (#A-860). Replacement eggs were not laid in artificial sites.

For natural sites at OR for which an early initiation date was estimated (n = 22), average initiation dates ranged from 3 March to 9 August for 22 first and single eggs, versus 24 May to 31 August for 4 replacement eggs. The earliest estimated initiation date for all sites at OR (single eggs at sites #701, #831 and S-223) was 23 February, and the latest estimated initiation date (replacement egg at site #357) was 15 September.

Disturbance of Artificial Nest Sites: On monitoring trips in July to November 2010, we found that several artificial nest sites at OR had been physically altered in the time between our trips, primarily involving the removal of backer boards and rocks that had been installed to enclose one end of each artificial nest site (see Figures 5a, 5b). Backer boards were removed from most of the 12 artificial sites deployed on the floors of the caverns at OR (i.e., 9 sites in July, 8 sites in August, 9 sites in September, 9 sites in October, 9 sites on 15 November). In addition, iButton wands had been pulled out of 9 and 7 artificial sites in July and August, respectively. Consequently, we removed all iButtons and wands in August. Mirrors had been pulled away from duct tape adhering to 7 artificial sites in July; consequently, these mirrors were not replaced. In addition, the floors of two artificial sites (A-847 and A-865) were observed to have partially collapsed. At A-847, a live chick was observed on the collapsed nest floor which was lower than where the egg had previously been observed. Nesting activity was unchanged at A-865, a site Ashy Storm-Petrels had not been recorded to have attended previously. Images from a reconnaissance camera deployed 15 September showed a Common Raven within the Upper

East Cavern on 22 October and 15 November (Figures 6a, 6b). The camera, speakers, and speaker wires appeared to be undisturbed. We suspect that some of the instances of disturbance of artificial sites in 2010 were caused by ravens; the instances of collapsed floors may have been caused by small earthquakes or natural settling of rocks.

Disturbance of Natural Nesting Habitat: Three natural nest sites were observed to have been physically altered during the summer months in 2010. Site #773 is located in the Upper East Cavern; it had a medium gawky chick with the site "partially destroyed by recent rockfall" on 12 August. Site #1031 is located in the passageway leading from the lower cavern to the upper west side of OR; it was empty and "partially collapsed" on 12 July, and empty and "completely collapsed" on 12 August. Site #1036 is located in the Upper West Cavern; it had a downy chick with a "heavily collapsed" site on 12 July, and empty and "completely collapsed" site on 12 August. In addition, the northeast end of the dirt floor of the Upper East Cavern was observed on 12 July and 12 August to have eroded; possibly, in part, due to researchers checking artificial nest sites in 2008-2010.

Artificial Nest Site Visitation by Storm-Petrels: Using iButton temperature loggers, visitation of Ashy Storm-Petrels at 9 additional artificial nest sites was documented in April-July 2010, in addition to artificial sites where egg-laying or presence was detected through monthly nest checks (Table 5; Appendix C). Common Ravens removed iButton wands from artificial nest sites in July and August, preventing later detection of storm-petrel attendance.

Temperature logger data indicated Ashy Storm-Petrel presence in all but one artificial nest site (tag #A-860) that showed use or visitation, as confirmed through regular nest monitoring in April-July (Table 5). Excluding the 13 July-12 August time period, the majority of detected visitations occurred on dates nearer to dates of new moons in each month., especially in nest sites where egg laying was not observed in 2010 (see Appendix C).

Only one artificial nest site (tag #A-868) known to been used regularly in 2010 showed consistent detections, indicating that adult storm-petrels likely sat near the iButton within this nest. Daytime attendance of this site by adults may have been disrupted on 21 and 30 April, and regular daytime attendance of this site by adults apparently ceased after 3 May (Appendix C-1). On 12 May, a dead small downy chick was found in this site; its estimated date of hatch was 27 April. This site was altered by ravens in the July through October period.

Common Raven: Common Ravens were commonly observed on or near the rock during our nest checks in 2010, as follows: two birds in flight on 15 April, one bird roosting on 12 July, two birds roosting on 15 September, and 1 bird roosting on 12 October. Evidence of probable raven predation of at least one Ashy Storm-Petrel was found in 2010, when a feather pile was observed in a photographic image of the floor of the Upper West Cavern, taken on 12 July.

Cassin's Auklet: Five occupied sites were documented in 2010; three sites fledged chicks, one had a failed egg, and one apparently was visited only (Table 6). A chick was assumed to have fledged if last observed as "small gawky" or older, and no dead chicks observed in crevices.

(a)

(b)

Figure 5. Images of artificial nest sites that had been disturbed by Common Ravens in (a) the "Upper West Cavern," and (b) "Upper East Cavern" at Orizaba Rock, 12 July 2010. A raven feather can be seen on the right center of the lower image.

(a)

(b)

Figure 6. Images of a Common Raven (see arrows in images) in Upper East Cavern at Orizaba Rock: (a) 22 October 2010; and (b) 14 November 2010. The raven in the lower image can be seen peering into an artificial nest site. The images were captured by a remote motion-sensing camera.

Table 5. Detected visitation of artificial nest sites by Ashy Storm-Petrels at Orizaba Rock in April-August 2010, based on iButton temperature logger data. The number of days in which storm-petrel presence was detected is presented by site. Artificial nests that successfully fledged chicks in 2010 are indicated in bold italics, with nesting status based on monthly nest monitoring. Dashes indicate no detection of storm-petrels. See Appendix C for specific daily detection information per nest site.

	Nesting Status[a]	16 Apr-12 May	13 May-13 Jun	15 Jun-12 Jul[b]	13 Jul-12 Aug[b]
A-847	U	6	6	-	-
A-848	NV	-	1	-	-
A-850	NV	-	1	-	-
A-852	NV	1	-	1	-
A-853A	NV	3	4	1	-
A-853B[c]	U	-	-	-	-
A-856	NV	-	3	-	-
A-858	NV	-	3	-	-
A-859	U	-	1	-	-
A-863	U	-	20	-	-
A-860	U	-	-	-	-
A-867	NV	1	2	-	1
A-868	U	19	2	-	-
A-869	V	-	-	-	-
A-870	V	1	2	-	-
A-871	NV	-	5	-	-
A-1066	NV	-	-	2	-

[a] Site nesting status based on data from regular nest-monitoring activities, as follows: NV = not visited, V = visited only, U = used (evidence of egg laying).

Table 6. Nesting activities[1] of Cassin's Auklets at Orizaba Rock in 2010.

Nest Number	23 Feb	12 Mar	15 Apr	12 May	14 Jun	12 Jul	12 Aug	15 Sep	Egg Number	Hatch	Fledge
tag #49	1B[1]	1B	0	0	1B	DC	0	0	1	1	Unk
tag #812	B/E	0[2]	0[2]	LG-MFC	Fthrs[3]	B	0	0	1	1	1
tag #999	0[2]	0[2]	0[2]	FFC	0	0	0	0	1	1	1
tag #1021a	B/E	B/E	DC	MFC	1B	-	-	-	1	1	1
tag #1021b	-	-	-	-	1B	0[2]	MFC	0	2	1	1
S-320	-	EF	0	NNC	0	0	0	0	1	Unk	Unk

[1] Abbreviations: B = adult bird, E = egg only, B/E = bird incubating egg, DC = downy chick, EF = eggshell fragment, FFC = fully-feathered chick, fthrs = feathers, LGC = large gawky chick, MFC = mostly feathered chick, NNC = nest not checked, 0 = empty nest.
[2] Nest site difficult to view, so "0" activity may not indicate absence, and presence of bird or chick may have been missed.
[3]Small pile of feathers at entrance; likely avian predation

Two sites (tags #812, #999) also had been used by Cassin's Auklets in 2009. One site (tag #1021) had been used by Ashy Storm-Petrels in 2009, but was not used by Ashy Storm-Petrels in 2010.

Black Oystercatcher: Adult Black Oystercatchers (*Haematopus bachmani*) were observed regularly at OR (4 adults in April, 4 adults in May, 2 adults in June, 2 adults in August). No oystercatcher scrapes, nests or chicks were noted during a complete survey on 12 May, nor during partial searches in other months.

Western Gull: Four Western Gull (*Larus occidentalis*) nests were observed on 12 May (contents: 3 eggs, 3 eggs, 1 egg, 1 egg).

Heermann's Gull): Adults and immature Heermann's Gulls (*Larus heermanni)* (counts combined) were observed roosting as follows: a) 14 June — 15; b) 12 August — 25; c) 15 September — 100; and d) 12 October — 1

Brown Pelican: Adults and immature Brown Pelicans (*Pelecanus occidentalis*) (counts combined) were observed roosting as follows: a) 14 June — 75; b) 12 August — 300; c) 15 September — 400; and d) 15 November — 50.

Evaluation of Storm-Petrel Nocturnal Behaviors: In 2010, 159 hours of video footage spanning 42 nights was collected at OR. Ashy Storm-Petrels were observed to directly interact with speakers broadcasting their vocalizations in both the lower and upper west cavern at OR. Exploration of artificial nests by Ashy Storm-Petrels was observed in the upper west cavern at OR. All video footage at OR (and half of the footage obtained at BC – see earlier) was examined to ensure image quality for future analysis and to determine all behavioral types exhibited by Ashy Storm-Petrels for future assessment of responses to social attraction at Santa Cruz Island. Because little is known of the behavior of Ashy Storm-Petrels, it is necessary to carefully describe behaviors before any quantification of the frequency of behaviors can be attempted.

To describe behaviors, multiple reviews of video segments with behaviors were performed to ensure proper interpretation and description of activities. However, in most cases, image quality was not sufficient to produce representative still images. The types of behavior observed, as well as those noted in the literature, were described within an ethogram (see Appendix B). Some video data from OR in May (4 nights) and June (3 nights) were not usable for assessing storm-petrel behavior due to salt build up on the camera lens. In Appendix B, some images of behaviors of birds reacting to the speaker systems at OR in both the lower cavern (Figure B-1) and upper west cavern (Figures B-2, B-3) are presented.

Hatching, Fledging, and Reproductive Success

Hatching, fledging, and reproductive success are summarized in Table 2. Overall reproductive success at natural and artificial combined at all monitored locations at Santa Cruz Island was 67% (n = 126) (Table 2).

Recruitment Study

A total of 50 Ashy Storm-Petrel chicks were fitted with PIT-tag bands (see Figure 7a; Appendix D) at Santa Cruz Island in 2010, as follows: BC (*n* = 24); CBE (*n* = 6); DSB (*n* = 12); and OR (*n* = 8). Only one chick (artificial nest site tag #A-863) from the two artificial nest sites that fledged chicks in 2010 was fitted with a PIT-tag band. In addition, three Ashy Storm-Petrel adults were fitted with PIT-tag bands during nighttime mist-netting efforts at Diablo Rocks, Santa Cruz Island, on 16 April 2010 (see below; Figure 7b; Appendix D).

Vocalization Recordings

Data were collected at BC and CBE were checked and archived but have not yet been analyzed.

Additional Surveys

Due to windy conditions and insufficient time on all monitoring trips in 2010, most additional surveys planned at Diablo Rocks, Shipwreck Cave and Gull Island were not conducted. On 15-16 April, mist-netting efforts were attempted at Diablo Rocks; specifically, at the larger offshore rock (Southeast Diablo Rock). Due to windy conditions, mist nets were only opened from 00:35 h to 02:20 h on 16 April. Three adult Ashy Storm-Petrels were captured and banded with USGS metal identification bands (band numbers: 4501-41291, 4501-41292 and 4501-41293) and PIT-tag bands (see Appendix D) between 01:00 h and 01:38 h, and one storm-petrel collided with and bounced out of the open mist net at 02:06 h. Several Ashy Storm-Petrels were observed flying by the closed mist net from 02:20 h to 02:30 h. Windy conditions during much of that night precluded more extensive mistnetting. During mistnetting efforts, Cassin's Auklet vocalizations were heard and presumed to originate from the southeast slope of Southeast Diablo Rock and Santa Cruz Island proper. One dead Cassin's Auklet chick was found dead at a burrow entrance on Southeast Diablo Rock, during brief examinations of nesting habitats there.

(a)

(b)

Figure 7. PIT-tag band attached to Ashy Storm-Petrels at Santa Cruz Island in 2010: (a) small gawky chick handled at a nest site at Diablo Rocks on 16 April; and (b) adult captured in a mist net at Diablo Rocks on 16 April.

DISCUSSION

Reproductive Success

Seabird restoration has focused primarily on improving habitat at breeding colonies to encourage attendance and recolonization, as well as to maintain or increase numbers of breeding birds and reproductive success (e.g., Parker *et al.* 2007). Reproductive success is one key demographic variable that should be measured for assessing population growth conditions and population changes over time. In Ashy Storm-Petrels, variation in reproductive success between locations and years clearly needs to be measured and reasons for variation assessed (Ainley *et al.* 1990, Sydeman *et al.* 1998b, McIver *et al.* 2009b, 2010).

In 2010, hatching success (74%; n = 139), fledging success (88%; n = 96), and reproductive success (67%; n = 126) at Santa Cruz Island (i.e., BC, CBE, BC and OR combined but omitting CPC) was generally greater than in 1995-98, but similar to 2005-09. As in 1995-98 and 2005, relatively high reproductive success values in 2010 occurred at CBE. However, reproductive success at DSB appeared to be lower than in previous years. In contrast to 1995-97 but as observed in 2006-09, reproductive success values at BC in 2010 were relatively high, in spite of a major reduction in colony size due to the skunk predation event in 2005. Ashy Storm-Petrels did not breed at CPC in 2010, apparently related to much greater colony impacts from the skunk predation event in 2008. Future monitoring will determine if the CPC colony has been extirpated or may eventually recover. However, the lack of breeding at CPC in 2010 suggests that long-term effects are likely and that new ways to assist recovery of this colony should be considered (discussed further below; see Appendix E).

In the absence of skunk predation, improved reproductive success in 2005-10 compared to 1995-98 mainly reflects higher hatching success and is consistent with: a) reduced levels of organochlorine contaminants which may no longer reduce reproductive success of Ashy Storm-Petrels on a population level (Carter *et al.* 2008b); and b) reduced avian predation in 2005-10 compared to 1995-97 (McIver 2002). However, these reproductive success rates do not include major impacts from skunk predation events at BC in 2005 and CPC in 2008. Relationships between organochlorine levels and eggshell thickness from eggs collected in 1992-2010 are being examined to better evaluate potential past and present effects from these contaminants (Carter *et al*., in prep.).

Despite slightly reduced fledging success in artificial sites due to Common Ravens, reproductive success at OR (natural and artificial sites combined) in 2010 appeared to be: (1) higher than in 1995-98; (2) relatively low compared to other locations in 2010 (as also noted in 1995-98); and (3) similar to hatching success observed in 2009. Sample sizes were low but fledging success in natural sites at OR appeared to be higher in 2010 than in 2009; successful fledging occurred in only two artificial nest sites at OR in 2010 compared to four sites in 2009. Disturbance of artificial sites at OR by Common Ravens likely reduced reproductive success of artificial sites and may have reduced numbers of eggs laid in artificial sites. Two of three natural sites observed as collapsed occurred in the caverns near artificial nests sites, and may have been altered by Common Ravens, although we could not determine if any adults, chicks or eggs in natural sites were predated by ravens while they were disturbing artificial sites. Despite lower hatching

success at DSB in 2010, fledging success at OR was comparable to: (1) BC and CBE in 2010; and (2) DSB in 1995-98 and 2005-09.

Breeding Phenology

Breeding phenology (or timing of breeding) is important for assessing natural factors affecting prey availability and adequacy of monitoring techniques. In 2010, breeding phenology was similar at BC, CBE, and natural sites at OR. Despite early egg laying at as many as three natural sites at OR, mean egg laying occurred approximately 4 weeks earlier at artificial sites at OR, compared to natural sites at OR, BC and CBE. However, egg laying occurred in both artificial and natural sites in late April and early May. Thus, egg laying in artificial sites likely involved experienced breeders that often breed earlier in the breeding season. In contrast, mean egg laying at natural sites at DSB occurred approximately 2 months later than at BC, CBE, and natural sites at OR. Excluding DSB and artificial sites at OR, most eggs were laid in June, most hatching occurred in late July and early August, and most fledging occurred in late September and early October.

Including natural and artificial sites, eggs were laid at Santa Cruz Island over a very long period (mean egglaying range = 202 d) in 2010, compared to 2005-09 (range 101-144 d), largely due to egg laying as early as 23 February in natural sites, and as early as 2 March in an artificial site. For natural sites only, eggs were laid over 159 d in 2010, similar to other years. In 2009, initiation of vocalization broadcasting at OR occurred on 28 March and may have facilitated early courtship and copulation, leading to slightly earlier egg laying in artificial sites in that year. This also may have been the case in 2010, given initiation of vocalization broadcasting on 14 April and most eggs (4 of 6) were laid 1-3 weeks later. However, egg laying at as many as three natural sites (#701, #831 and S-223) was observed on 23 February, and at one artificial nest site (tag #A-868) egg laying was observed on 12 March, about one month before vocalization broadcasting. Causes for earlier initiation at some sites at OR in 2010 are not known.

Causes for the unusual delayed egg laying at DSB in 2010 are not known. On our first visit in August, we did not find any evidence of a high water event that may have washed away nests or affected adults attending nests prior to egg laying. However, such an event clearly occurred at CBE at some point between February and mid May, with much alteration to breeding habitats in the front of the cave which had not been previously noted since monitoring began in 1995. Windy and high swell conditions persisted late into the spring in 2010 which may have resulted in a relatively late high water event at DSB, although alteration to breeding habitat was not observed at DSB. Numbers of active nests in DSB in 2010 appeared to be slightly lower than in previous years (McIver *et al*. in preparation). Possible impacts on adults, loss of early nests, greater numbers of replacement clutches, or delayed breeding also may have contributed to lower hatching success in 2010.

Restoration at Orizaba Rock

Vocalization broadcast systems with or without additional attractants (e.g., decoys, mirrors) or artificial nesting habitats have been successfully used to attract seabirds to attend and recolonize colonies of Common Murres (*Uria aalge*), Atlantic Puffins (*Fratercula arctica*), Dark-rumped

Petrels (*Pterodroma phaeopygia*), Band-rumped Storm-Petrels (*O. castro*), Common Terns (*Sterna hirundo*), Arctic Terns (*S. paradisaea*), and Ashy Storm-Petrels (Kress 1983; Kress and Nettleship 1988; Podolsky and Kress 1989, 1992; Bolton *et al.* 2004; Parker *et al.* 2007; McIver *et al.* 2010). In 2010 at OR, signs of continued success with restoration efforts included continued breeding at most of the artificial sites that were used in 2008 and 2009, and relatively high numbers of natural sites comparable to numbers observed in 1996 and 2009. However, Common Ravens disturbed artificial nest sites at OR during the summer of 2010, likely disrupting breeding efforts and reducing reproductive success of Ashy Storm-Petrels in artificial sites (see below "Avian Predators"). In 2011, we plan to replace all artificial nest sites located on the upper cavern floors, and many artificial sites located on the ledge in the Upper West Cavern, with newly-designed artificial nest sites constructed of ceramic (i.e., clay fired at extremely high temperatures) and designed to be more enclosed and less accessible to avian predators. These new nest designs will include: (1) a more concealed and smaller nest entrance; (2) a more concealed and larger nest chamber; and (3) ceramic floors to prevent ravens or other avian predators from digging under the nest body and dislodging the artificial nest site. In addition, to reduce potential for raven attraction, new nest sites will not be marked with metal or plastic nest tags; instead, identification numbers will be etched into the clay above the nest entrance prior to firing (see Figure 8).

Numbers of active nests at OR have increased from 14 sites (all natural) in 2007, to 24 sites (20 natural and 4 artificial) in 2008, to 26 sites (20 natural and 6 artificial) in 2009, to 29 sites (23 natural and 6 artificial) in 2010. Similar levels of nesting at OR occurred in 1995-97, when a peak of 27 sites (all natural) occurred in 1996. Numbers of natural sites have increased over 200% from 7 in 2005 to 23 in 2010 and have essentially recovered to 1995-97 levels. We suspect that at least a portion of this rapid recovery can be accounted for through heightened attendance and breeding of birds either raised at this colony or elsewhere that were encouraged by broadcasting vocalizations and providing additional breeding habitat in artificial nest sites. However, we also suspect that large numbers of new breeders may reflect relatively high numbers of subadults naturally attempting to breed at Orizaba Rock in 2008-10. Higher reproductive success has been accompanied by lower pollutant levels, lower avian predation, and possibly reduced squid fishing off the north side of Santa Cruz Island. Assuming that juvenile and subadult survival has remained the same or improved over time, more subadults near the age of first breeding should have been attending the colony in 2008-10 than in 1995-97.

In addition to increasing colony size by providing additional breeding habitat at OR, one of the key values of using artificial sites at OR was to help better protect a portion of the colony from predation and human disturbance. Although our initial design worked well for two years (2008-09), disruption by ravens in the third year (2010) indicated that the design of artificial sites needed alteration. Deployment of more protected artificial nest sites should discourage ravens from investigating these sites.

In the future, numbers of storm-petrel nests at OR should continue to increase to even higher levels due to substantial augmentation of the number of potentially suitable nest sites through deployment of 30 artificial sites to date and possible addition of more artificial nest sites in the future. If 30 or more artificial nest sites are eventually used and natural nest sites also continue

Figure 8. Prototype of newly re-designed artificial nest site for deployment at OR in 2011. On the left, a ceramic artificial site for deployment on the floors of the caverns, each with a ceramic floor, small entrance, and top hatch for accessing chicks. On the right, protective collar pieces for modifying the front entrance of cement roof tiles on ledges in the Upper West Cavern.

to be used, the OR colony will double in size. However, some artificial nest sites may not be used for various reasons. Some sites may be slightly more suitable than others and the dense arrangement of artificial nest sites within available space might prevent complete occupancy due to issues related to nest site access and territorial behavior at nest site entrances. We did not have any better options for deploying artificial sites at OR due to limited unused space in caverns. By filling most available space, we provided as many opportunities for prospecting storm-petrels as possible and let the storm-petrels decide which sites they would use or not use over time.

A larger OR colony with a greater proportion of more protected nest sites should have a greater ability to withstand certain anthropogenic impacts, reducing the probability of extirpation of this relatively small colony over the long term. Such anthropogenic impacts may include: (1) increased avian predation related to bright lights from squid fishing or other boats; (2) increased predation related to higher populations of avian predators; and (3) human disturbance from researchers or non-researchers). Predation of storm-petrels by island spotted skunks is unlikely at OR, because the offshore rock is detached from the island (~ 50 m), island spotted skunks at Santa Cruz Island frequent coastal sage scrub habitats (Crooks and Van Vuren 1994), which are not present on OR, and thus skunks on the island are not likely to swim to the rock). Larger colony size (with at least adequate reproduction) is a great benefit, especially if natural factors affecting breeding remain similar and potential anthropogenic factors are addressed.

In 2010, video camera systems deployed in remote sites at Santa Cruz Island successfully gathered data on within-colony behaviors of Ashy Storm-Petrels. Various behaviors were described, including investigations of artificial nest sites and responses to speakers broadcasting vocalizations. Further experimental design is needed in 2011 to statistically evaluate storm-petrel activities and behaviors. For example, it would be valuable to compare: (1) behavioral responses with and without vocalization broadcast; and (2) different sound treatments (e.g., Podolsky and Kress 1989, 1992). The ethogram created in the 2010 pilot study (Appendix B) will assist in quantifying the types of behavioral responses associated with restoration techniques under different social attraction treatments at Santa Cruz Island in 2011.

Skunk Predation at Sea Caves

Bat Cave: Though skunks have not been detected during monitoring in 1995-2004, at least two island spotted skunks somehow gained access to BC in 2005; at least 70 adult Ashy Storm-Petrels were killed and complete reproductive failure occurred (McIver and Carter 2006). Numbers of active nests were greatly reduced to only 19 active nests in 2006 but have increased rapidly since then as follows: 28 in 2007; 35 in 2008; 48 in 2009, and 60 in 2010 (Table 2). BC appears to be experiencing a rapid natural recovery, perhaps facilitated by: (1) survival of many adults during the initial 2005 predation event; (2) recruitment of many new birds (either raised at this colony or elsewhere); and (3) relatively low avian predation. Relatively high reproductive success also has occurred at BC since 2005, encouraging continued breeding by remaining adults. If skunks do not gain access to this cave again, we expect that this colony will eventually recover. No evidence of skunk access has been noted in 2006-10.

Cavern Point Cove Caves: While skunks were not detected during monitoring in 1995-2007, at least two island spotted skunks gained access to CPC in 2008. At least 32 adult Ashy Storm-

Petrels were killed and complete reproductive failure occurred. Only 14 nests had been found in 2007, such that the loss of 32 adults or subadults appeared to represent most breeders and some future breeders at this small colony. Only two active nests found in 2009 (tags #54 and #1040 in Cave #5) and no active nests were found in 2010. We suspect that few adult storm-petrels escaped skunk predation at CPC in 2008 due to a small amount of nesting habitat with relatively low ceilings and entrances. Future monitoring is needed to determine if this colony has been extirpated and whether it recovers or not. Special efforts to restore this colony may be warranted in the future, if skunk predation can be prevented or considered highly improbable. No evidence of skunk access was noted in 2009-10. At CPC (and at BC), the potential for predation of Ashy Storm-Petrels by island spotted skunks is likely to be an issue for the next several years. Despite low numbers of nesting attempts at CPC in 2009 (n = 2), and no nesting in 2010, Ashy Storm-Petrels may continue to attempt to breed at CPC in future years because progeny from nests in 2007 and earlier will return to attempt breeding for several more years. Skunk-trapping efforts to protect Ashy Storm-Petrels were implemented during the Ashy Storm-Petrel breeding seasons in 2009 and 2010, and are expected to occur in subsequent years. Ultimately, because Ashy Storm-Petrels will likely continue to attempt to breed at CPC, the greatest protective measure that can be provided at this location is the availability of numerous nesting crevices that are inaccessible to island spotted skunks, yet accessible to Ashy Storm-Petrels. To protect Ashy Storm-Petrels from predation by island spotted skunks, specially-designed artificial nest sites should be deployed in CPC#4 and CPC#5, each with a nest entrance that is small enough to exclude island spotted skunks, yet permit access by Ashy Storm-Petrels (see Appendix E). In addition, social attraction (broadcast vocalizations) could be employed to attract Ashy Storm-Petrels to re-attend and again breed at this location. Specially-designed elevated artificial habitats could be provided near speakers to encourage some birds to nest in those artificial sites where they would be partly protected from any potential future skunk predation. Such efforts would likely be most effective within 10 years of the skunk predation event (i.e., before 2018) because most young birds that were raised at this colony will be returning and attempting to breed during this period.

General: Prior to these events in 2005 and 2008, skunk predation of Ashy Storm-Petrels at Santa Cruz Island was not known to occur and had not been documented during monitoring in 1995-2004 (McIver 2002; W.R. McIver and H.R. Carter, unpubl. data). In recent years, island spotted skunk population numbers at the island have increased dramatically, possibly in response to reduced numbers of island foxes (*Urocyon littoralis santacruzae*), changes in island vegetation, or a combination of these and other factors (Jones *et al.* 2008). Given major impacts to Ashy Storm-Petrels by 1-2 skunks in 2005 and 2008, it is highly unlikely that this has occurred at least since the 1980s. Future monitoring will allow evaluation of the ability of Ashy Storm-Petrel colonies to recover from such events, as long as these events do not occur often. While island skunk populations remain at unnaturally high levels on Santa Cruz Island, it is appropriate to protect nesting Ashy Storm-Petrels. The island fox population at Santa Cruz Island, while still well below historical numbers, appears to have slowed its steep decline of the 1990s and increased its numbers (Bakker et al. 2005, 2009). In 2010, no island spotted skunks were detected or captured in any of the Ashy Storm-Petrel colonies, but continued preventative efforts (i.e., trapping and protective nesting crevices) and monitoring will be necessary to ensure that these caves remain free of skunks and suitable for nesting by Ashy Storm-Petrels for at least several more years into the future.

Avian Predators

During monitoring in 1995-98, Barn Owls were well documented as predators of Ashy Storm-Petrels at Santa Cruz Island, especially at BC, CPC, CBE, and OR (McIver 2002). However, during monitoring in 2005-09, predation by Barn Owls has been much reduced. Western Gulls are known predators of Ashy Storm-Petrels at Southeast Farallon Island where both breed in the same parts of the island (Ainley *et al.* 1990, Sydeman *et al.* 1998a). At Santa Cruz Island, single Western Gulls have been rarely observed to fly inside sea caves during nest monitoring and only a few pairs of gulls nest on OR with little evidence of gull predation on seabirds there (McIver 2002). Peregrine Falcons are commonly observed near Ashy Storm-Petrel breeding locations at the bases of steep cliffs (McIver 2002; W. R. McIver, H.R. Carter, and A.L. Harvey, *unpublished notes*), although predation of storm-petrels by falcons at breeding colonies is unlikely due to nocturnal visitation of breeding colonies by storm-petrels.

Common Ravens are commonly observed near Ashy Storm-Petrel breeding locations and have been documented in sea caves (e.g., CBE in 1997 [McIver 2002]) and at OR in 2010 [this study]) and may prey on storm-petrels. However, in 2010, upon our arrival at OR, ravens were often observed roosting on OR at least since April, whereas in other years they usually were observed flying near the rock without regular roosting or close association with the rock. Reasons for higher roosting or attendance in 2010 were not determined but may have partly reflected attraction to the rock by broadcasting of vocalizations and monitoring activities in 2010 or previous years. For example, ravens that typically attend camping areas on east Santa Cruz Island likely forage more widely in winter and spring when camping is much reduced. At least one raven visited the upper caverns at OR and was actively investigating artificial nest sites based on: (1) altered artificial nest sites found from July through November 2010; and (2) images captured by a reconnaissance camera in October and November 2010. Watanuki (1986) reported that Jungle Crows (*Corvus macrorhynchos*), which are the size of Common Ravens, excavated Leach's Storm-Petrel (*O. leucorhoa*) burrows and ate storm-petrel adults, eggs, and chicks. At OR, we found evidence (i.e., feather pile in proximity to artificial nest sites) that at least one adult Ashy Storm-Petrel was killed by an avian predator in 2010, likely a raven. The regular occurrence of at least one raven in the upper caverns at OR in July to November suggests that there was a reason for ravens to return to inspect artificial sites on a regular basis. Possibly, it successfully obtained an adult and/or egg and returned regularly to search for more prey. In 2009, we asserted that artificial nest sites at OR seemed deep enough (36 cm) to prevent avian predators from reaching incubating adults, eggs or chicks inside the site. This assertion assumed that: (1) an avian predator could only access a storm-petrel from the main entrance of the artificial nest site; and (2) storm-petrels would likely nest deep in the nesting chamber and out of reach of potential avian predators with short bills. We did not anticipate that a raven could remove the backer boards from the back sides of the artificial sites which were secured with rocks. In addition, the linear design of the artificial nests sites likely facilitated visual inspection of nest contents by ravens (see above "Restoration at Orizaba Rock"). Many natural sites at OR are more shallow than these artificial sites but usually are not directly visible from a distance and were likely are less obvious to ravens to consider inspecting.

Common Ravens have been common breeders at Santa Cruz Island for at least the past 120 years (Blake 1887, Garrett and Dunn 1981). Anthropogenic food sources at the island available for

ravens have varied since the late 19th century, and have included dead livestock (e.g., sheep) and food from human tourists and associated campgrounds (Blake 1887, CINP *unpublished notes*). Common Ravens are known to be adept at obtaining food from campgrounds, including using techniques such as opening cardboard boxes and coolers, and unzipping backpacks. Vermeer *et al.* (1993) suggested that predation of guillemots by Northwestern Crows (*Corvus caurinus*) may have been related to crows following researchers. Considered together, these behaviors exhibited by corvids suggest that at least one raven has become experienced with opening artificial structures through foraging in camping areas at Santa Cruz Island, and has cued into vocalization broadcasting or researcher visitation to OR. At OR, providing more protected artificial nesting habitat, and fortifying and augmenting (with ceramic pieces) shallow natural crevices in close proximity to artificial sites, should prevent ravens from depredating Ashy Storm-Petrels at nest sites at OR.

Ashy Storm-Petrels are not easy for most diurnal avian predators to detect, arriving and departing from nest sites and colonies at night. Incubating adults and chicks before fledging age (~80 d) also are generally non-vocal and inactive within their nesting crevices during the day. Near fledging age, older chicks can move outside of nest sites in sea caves but rarely vocalize. A few smaller non-handled chicks also make peeping or begging sounds while we are checking nests but this may reflect minor disturbance to chicks from our activities (e.g., use of flashlights) and does not occur regularly. As described above, it is possible that at least one raven (possibly a campground dweller) cued into social attractants and our presence at OR, and this led to the death of at least one Ashy Storm-Petrel adult, and possibly a chick, in 2010.

Compared to 1995-98, relatively low levels of storm-petrel predation by avian predators (i.e., few carcasses or feather piles) at Santa Cruz Island locations appeared to occur in 2010, as also noted in 2006-09. However, lower numbers of breeding storm-petrels also occurred at BC and CPC in 2005-10, due to skunk predation events. More work is needed to summarize and assess past predation data for comparison to 2005-10 data. At BC, Barn Owls may have switched to hunting elsewhere, due to the reduction in storm-petrel numbers. Future monitoring of predation during storm-petrel nest monitoring will generally assist our understanding of the frequency and type of predation upon storm-petrels. However, greater effort would be needed to better assess predators through predator surveys and analysis of prey remains at nests and roosts away from storm-petrel colonies.

High Water Events at CBE

Major changes to nesting habitats near the entrance to CBE occurred in 2010 and two dead adults or subadults were recorded, apparently due to high water events related to winter and/or spring storms as late as May. Only 21 nests were recorded in CBE in 2010, compared to 24-29 nests in 2006-09. This habitat change and loss of some birds may have resulted in some breeding pairs not being able to relay elsewhere in the cave in 2010, either because: (1) both adults were killed by high water events; (2) one adult was killed but the other adult was not able to find a mate in time to breed elsewhere in the cave in 2010; or (3) some surviving adults might have continued attending old nest site areas without laying eggs. Interestingly, only 13 nests were found in 2005 which might have reflected an earlier year with high water events; by 2006, 24 nests were present, representing an 85% increase from 2005 and suggesting that a substantial portion of

breeding adults did not breed in 2005. Future monitoring will help us assess whether some storm-petrels were killed or did not breed in 2010 and whether slow or rapid recovery occurs.

Pigeon Guillemots at CBE

A large increase in the numbers of Pigeon Guillemot nests was found at CBE in 2010 (Table 4). Twenty-one nest sites were recorded and monitored versus only 7-10 nests in 2006-09. Ten (47.6%) of 21 nests had only one egg clutches, possibly suggesting many first-time breeders (Asbirk 1979). For 19 nests with known fates, 16 (84%) hatched at least one chick, 15 (94%) of 16 nests fledged at least one chick, and 15 (79%) of 19 nests with eggs fledged at least one chick. In general, reproductive success in 2009-10 (with no predation recorded) was relatively high compared to 2006-08 (with extensive predation recorded). Reduced avian predation in 2009-10 likely had led to this increase. To date, increased numbers of breeding guillemots at CBE have not appeared to directly affect Ashy Storm-Petrels, but some storm-petrel nest sites may be usurped by guillemots in the future.

Cassin's Auklets at OR

An increase in the numbers of Cassin's Auklet nests was found at OR in 2010, along with highly successful breeding as noted at other CINP breeding locations (Table 5). Five nest sites were recorded and monitored versus only 0-3 nests in 2005-09. An apparent second clutch by the same breeding pair also was laid in one site (#1021). For 3 single/first eggs with known fates, all hatched and fledged. The sole second clutch also hatched and fledged. In general, reproductive success in 2010 was very high compared to no successful fledging in 2005-09. Improved prey resources appear to be largely responsible for increased numbers of nests and high reproductive success in 2010. Increased numbers of breeding auklets at OR did not appear to directly affect Ashy Storm-Petrels, but some storm-petrel nest sites may be usurped by auklets in the future, especially if this small colony continues to grow.

Human Visitation

Potential effects of human visitation on storm-petrel nests and nesting habitat at OR were observed. Three nest sites were observed as collapsed, although it was not clear if this was human or raven caused, or perhaps naturally-occurring event, caused by a small earthquake and/or settling rocks. However, a dirt floor portion of the Upper East cavern clearly had eroded and slumped in an area where researchers usually sit beside while checking artificial nests. While researchers are careful to avoid any impacts to fragile nesting habitats, additional efforts to deploy and monitor artificial nest sites in the Upper East in 2008-10 apparently caused sufficient damage to lead to erosion, mainly due to wind and spray when researchers were not present.

Natural and artificial nesting habitats at OR and in sea caves 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 or disturbed by unaware human visitors. No evidence of non-researcher human visitation was documented at BC, CBE, CPC, or DSB in 2010. While human visitation at CPC and BC was observed in 1995-

97 and 2005-09, no evidence of human presence was found at these sites after signs were deployed in 2009, indicating the signs may dissuade tourists from entering caves.

Monitoring and Restoration Recommendations for 2011-12

At OR, the Montrose Trustee Council previously decided to fund vocalization broadcasting and maintenance of artificial nest sites through 2011 (i.e., for a total of four years from 2008-11), prior to evaluating what continued efforts would be necessary. However, due to significant impacts to artificial sites from ravens in 2010, we are replacing or modifying most artificial sites in 2011 with new "raven-proof" sites (see Figure 8). We recommend that vocalization broadcasting should be continued at least in 2012-17 for two main reasons: (1) to provide a minimum of four years of social stimuli for encouraging storm-petrels to attend and breed at new artificial sites, following three years of prior efforts in the same location with the original artificial sites; and (2) to ensure that the new design of artificial sites is adequate for long-term use at this location and if necessary implement further modifications to artificial sites in 2012 or later. We suggest that evaluation of future social attraction efforts and use of artificial sites should now occur after the 2012 season.

Regardless of the degree of continuing restoration work after 2012, artificial sites should remain on OR, with at least one field trip per year in March-April for maintenance prior to egg laying to ensure that artificial nest sites remain suitable for nesting. In most years, maintenance likely will not be required at most sites but, by ensuring that all sites are suitable each year, the maximum number of artificial nest sites will become occupied. Artificial habitat at OR will also facilitate future nest-monitoring efforts.

We recommend continued nest monitoring work at OR and Santa Cruz Island sea caves in 2011-12 for the following reasons:

- documenting the degree of egg laying and visitation of new artificial nest sites at OR
- assessing the design of new artificial nest sites for making further alterations as needed
- measuring reproductive success in artificial and natural nest sites at OR and at natural sites in BC, CPC and CBE. However, we will discontinue monthly visits to DSB for safety reasons
- determine the total numbers of nests at OR, BC, CPC and CBE
- determine an index of the numbers of nests at DSB based on one visit in August, if sea conditions allow
- identify and address natural and anthropogenic factors that might affect growth in colony size and continued high reproductive success

After investing significant effort to restore this colony in 2008-10 and gathering monitoring data in 2006-10, full-scale monitoring should be continued in 2011-12 to ensure project success prior to evaluating any change in project design during and after the 2012 season.

We recommend the following restoration work at OR and Santa Cruz Island sea caves in 2011-12:

Artificial Nest Sites at OR

- March-April: replace some artificial nest sites composed of roof tiles with custom-made artificial nest sites made of clay and fired at high temperatures. In addition to preventing raven predation, these sites will allow access to chicks and iButtons by researchers without alteration of the nest site (i.e., lifting of cement roof tile).

- March-April: refurbish artificial nest sites with gravel and sand, as necessary.

Natural Nest Sites at OR

- To the extent feasible, rebuild and fortify (using customized pieces of ceramic) the three natural crevices that were observed as collapsed during 2010. For example, a customized ceramic roof and nest entrance could be placed over site #1031, located in the floor of the passageway leading from the lower cavern to the upper west side of OR. This would restore the crevice nature of this site. Ashy Storm-Petrels previously nested in this site for several years.

Vocalization broadcast at OR

- March-August: Deploy and operate the vocalization broadcast system. We believe that early deployment prior to the main egg laying period season is important for potential attraction of birds (especially those from other colonies) to attend and breed at OR. By using newly-modified artificial sites, we plan to prevent any raven predation by individual ravens inspecting artificial sites, even though we still may be attracting some ravens to OR with early broadcasts. We hope that these individual ravens will be discouraged and stop attending OR when they find that artificial sites cannot be accessed. We will assess whether continued raven roosting occurs at OR in 2011-12. Broadcasting should continue in 2011-17. However, if ravens are still regularly attending OR by 2012, we may consider other methods of discouraging their presence.

- Shut down and remove part of the system during the August field trip to prevent attraction of non-breeding birds after the egg-laying period which could lead to increased predation of inexperienced birds in fall.

Ashy Storm-Petrel Behaviors at OR

- In 2011, further evaluate Ashy Storm-Petrel behaviors in relation to broadcast vocalizations and artificial sites by comparing filming behaviors with cameras on one

night without broadcasting versus an adjacent night with broadcasting. Logistically, we will only be able to conduct one such comparison per trip in late May to late August 2011 (n = 4 trips). Future behavior work will depend on the success of this work in 2011.

Ashy Storm-Petrel Vocalization Levels at CBE, BC and CPC

- In 2011, we will collaborate with the University of California Santa Cruz (UCSC) to use acoustic recorders to measure vocalization levels at CBE, BC and CPC for comparison to numbers of active nests. Recorders will be deployed in March and removed in October. Both 2010 and 2011 data will be analyzed.

Recruitment of Ashy Storm-Petrels at OR and sea caves

- Because Ashy Storm-Petrels are highly philopatric, most recruitment to OR and sea cave colonies is likely derived from locally-fledged chicks, with a few from other colonies. To better understand how the OR colony and sea cave colonies are recruiting breeding birds over the long term, the PIT-tag study of chicks and subsequent search for future breeding of those birds should occur at all monitored locations. We have incorporated the use of PIT-tag readers and wand antennas into our nest monitoring protocol for each nest site to search for the presence of PIT-tags with after-hatch-year storm-petrels observed in nest sites during nest monitoring visits in future years.

Ashy Storm-Petrel protection from skunks at sea caves

- Continue to implement a storm-petrel protection plan to prevent skunk predation of storm-petrels at CPC, BC, and CBE, using trapping techniques.

- 2011-future years: Gather information on population size, distribution, and behavior of island spotted skunks at Santa Cruz Island from other researchers.

- Deploy specially-designed ceramic artificial nest sites at CPC to provide nesting crevices that are inaccessible to island spotted skunks, but accessible to Ashy Storm-Petrels (see Appendix E). For each artificial nest in both caves, a mixture of small pumice stones, sand, and dirt would be placed inside, for suitable nesting substrate. These artificial sites would be deployed in the rock/rubble pile in CPC #5, amongst and underneath rocks and boulders that presently exist there. In CPC#5, the nest entrances of each artificial site would be oriented to face away from the cave entrance, to minimize effects of potential wintertime wave wash of nesting substrate. These specially-designed sites should also be placed in CPC #4, in the same relative locations as the roof tiles that are currently deployed there. This is a protective measure for Ashy Storm-Petrels at CPC, but also could be used at BC, to prevent or minimize future predation events by island spotted skunks there.

Additional Colony Surveys

Occasional nest surveys may be conducted at Diablo Rocks and Shipwreck Cave if and when conditions and time allow to develop baseline data for assessing trends in numbers of breeding birds in accessible areas at these locations.

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Appendix A.

Assessment of Ashy Storm-Petrel vocalizations and behaviors in relation to social attraction techniques and artificial habitat at Orizaba Rock, Santa Cruz Island, California

2010 INTERIM PROGRESS REPORT

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INTRODUCTION

In 2006-10, a team of seabird biologists (composed of U.S. Fish and Wildlife Service (USFWS), Channel Islands National Park (CINP) and Carter Biological Consulting (CBC)) were funded by the Montrose Trustee Council (MTC) to monitor and restore Ashy Storm-Petrels (*Oceanodroma homochroa*) at Orizaba Rock off Santa Cruz Island, California, using social attraction (broadcast vocalizations) and artificial nest sites (MSRP 2005, McIver et al. 2010). Restoration work in 2008-10 has already demonstrated much apparent success, with nesting use of some artificial nest sites and an overall increase in the number of active nest sites on Orizaba Rock. Restoration and monitoring efforts are currently scheduled to continue through 2011, followed by post-restoration monitoring.

In 2010, Simon Fraser University (SFU) was added to the restoration team with funding by the MTC to help develop additional information for evaluating success of the restoration project. A collaborative experimental pilot project by SFU and other team members has focused on the 'Assessment of Ashy Storm-Petrel vocalizations and behaviors in relation to social attraction techniques and artificial habitat at Orizaba Rock, Santa Cruz Island, California'. In April 2010, automated infrared cameras were deployed at two colonies (Orizaba Rock and Bat Cave; one colony with social attraction and one without) in an attempt to gather baseline information about the behavior of this rare storm-petrel species and its behavioral response to social attraction. In addition, Automated Recording Units (ARUs) were deployed at two colonies without social attraction to gather information about the acoustic behavior of the species in sites unaffected by acoustic interference from the social attraction system. Data are in the process of being stored and cataloged for current analysis by SFU and possible future additional analysis by the Montrose Settlements Restoration Program (MSRP).

The main goals of the pilot project are to:

- Describe and catalogue behaviors associated with breeding and responses to broadcast vocalizations by Ashy Storm-Petrels in 2010.

- Collect recordings of Ashy Storm-Petrel acoustic behavior in 2010.

- Develop appropriate experimental/statistical treatments and analysis methods for Orizaba Rock in 2011 to demonstrate whether broadcast vocalizations invoke attraction to broadcast vocalizations and which behavioral attributes are associated with reproduction.

This report provides a brief summary of work to date during the 2010 experimental pilot study and lists recommendations for future project implementation.

METHODS

Infrared Cameras

Three infrared cameras were deployed in Ashy Storm-Petrel breeding colonies at Santa Cruz Island in April 2010 (Figure 1, Figure 2). Two cameras were placed in separate caverns at Orizaba Rock (OR; upper cavern & lower cavern), and one was positioned at Bat Cave (BC). The cameras were designed to withstand harsh marine conditions, with the bulk of the electronic components housed inside protective casing. Each infrared camera was fitted with the following components:

- DVR (Digital Video Recorder)
- Power supply timer unit
- Spot monitor
- 32GB SDHC card
- Battery
- Charger
- Pc168 IR camera
- Weatherproof Microphone
- Camera mount

Figure A-1. Infrared camera components used to film Ashy Storm-Petrel behavior at Santa Cruz Island in 2010 (Photo by L. Halpin).

Two cameras were deployed at OR: one in the upper cavern and one in the lower cavern (Figure 2). One camera was deployed at BC in a natural setting without social attraction (i.e., control location).

Figure A-2. Infrared camera mounted for filming at Orizaba Rock Upper Cavern. (Photo L. Halpin, 2010)

Cameras were securely mounted to cave walls to film in areas where Ashy Storm-Petrels are known to breed. At OR, one camera filmed in the upper cavern with a view of the artificial habitat and vocalization speaker; in the lower cavern a camera was mounted with a clear view of the natural habitat and a vocalization speaker. In BC, a camera was mounted on a tripod to film an area of natural driftwood habitat where Ashy Storm-Petrels nest. Each camera runs on a scheduling system which activates the camera and DVR at 22:30h each night and continues to film until 02:30h. This schedule is designed to capture the peak nocturnal activity periods for Ashy Storm-Petrels based on mist-net captures in the Channel Islands (H. R. Carter, unpubl. data).

Automated Recording Units (Songmeter-2)

In addition to the infrared cameras, two Autonomous Recording Units (ARU, Figure 3) were deployed from April to August 2010: one at Cave of the Birds Eggs (CBE), and one at BC. These units were deployed in the field in an attempt to gather acoustic behavioral information about the species.

Devices were programmed to record for 1 minute in every 10 minutes from 18:00h to 22:59h, and then continuously from 23:00h to 02:59 h, and for 1 minute in every 10 minutes from 03:00h to 06:00h. The devices recorded successfully on this schedule every night from deployment on 15 April 2010 and will continue to record until planned removal from the field in September 2010.

Figure A-3. Songmeter-2 Automated Recording Unit (ARU) at Cave of the Birds Eggs. (Photo by L. Halpin 2010)

DATA COLLECTION

Nocturnal Video Footage

Infrared cameras successfully recorded footage for an average of 4 nights per month with approximately 4 hours per night. Each of the infrared cameras obtained approximately 16 hours (4 nights) of footage per month. From April to August almost 240 hours (322 gigabytes) of nocturnal video footage was obtained from all three cameras at Santa Cruz Island.

Some problems have occurred throughout the season where extreme weather has caused debris and spray to cover the lens of cameras. This has resulted in some footage becoming unusable. However, there is potential to avoid or minimize this problem in future months by applying an invisible marine-based wax coating to deflect moisture from the lens cover.

Automated Recording Units (ARU)

The ARUs successfully recorded 4 hours and 49 minutes of acoustic data each night from April 15 2010 to July 15 2010. Wind and wave noise has caused some data to become problematic for analysis, but hopefully the use of various sound filters will minimize this problem. Software will be used to analyze a

sample of recorded calls and produce spectrograms for visual representation; and to examine the frequency of the main types of vocalizations observed throughout the breeding season.

Recordings by Ben Clock (Cornell Lab of Ornithology)
Benjamin Clock made high quality recordings of Ashy Storm-Petrels at Santa Cruz Island in April 2010. These recordings will be used for sample analysis of Ashy Storm-Petrel vocalizations, and for creating any mp3 sound files for future speaker broadcast vocalizations. CDs for mist-netting use may also be created due to the high quality of the recordings.

DATA ANALYSIS & RESULTS

To date, much time has been and will be expended on: a) task of cataloging Ashy Storm-Petrel behavior for creating an ethogram or a catalog of behavior types and activities displayed; and b) reviewing literature on Ashy Storm-Petrel and other storm-petrel behaviors, especially the better-studied Leach's Storm-Petrel (*O. leucorhoa*), Fork-tailed Storm-Petrel (*O. furcata*), and European Storm-Petrel (*Hydrobates pelagicus*) (e.g., James-Veitch, 1970; Boersma et al., 1980; Simons, 1981; Ainley, 1995; Huntingdon et al., 1996; Warham, 1996; Brooke, 2004).

The software package Etholog 2.2 is used for transcription and timing of behavior events observed in the video data. This computer program allows the user to pre-define behavioral categories. The software then registers sequence and timing of behavior events and allows the user to export the data in suitable files for subsequent analyses. Because it is not possible to distinguish between individual birds, visits and behaviors will be recorded as single petrel events.

Once behavior types are fully categorized, they will be assessed by frequency of behavior type, duration of behavior (per event), number of visits per period and the duration of visits (per event, multiple behaviors may be displayed in a single event).

DISCUSSION

The 2010 experimental pilot study has proven that we can successfully collect large quantities of video footage and acoustic data of Ashy Storm-Petrel behavior, perhaps beyond initial expectations. However, the study design should be adapted by applying standardized treatments that will allow for appropriate statistical testing of the effect of the speaker system on petrel behavior. Through project design meetings with Laurie Harvey, Bill McIver and Harry Carter, we have determined that a system of speaker treatments will be useful in enhancing the methodology for 2011.

The application of treatments will likely involve correlating Ashy Storm-Petrel behavior events with 3 treatments:

1. Single ASSP vocalization broadcast.
2. Multiple ASSP vocalization broadcast.
3. No vocalization broadcast.

This results in the need to adapt the current speaker system to work on a timed schedule. Discussions

with the manufacturer (Susan Schubel) are ongoing. Progress so far indicates that this modification is possible.

Once behavior types are fully categorized, they will be assessed by the frequency of behavior type, duration of behavior type (per event), number of visits per period and the duration of visits.

The treatments for each site using the off/single/multiple vocalization schedule will allow for a standardized methodology that can be tested statistically using a General Linear Regression Model (GLM), and appropriate ANOVA to test for a statistically significant difference between mean visit duration, mean number of visits, mean frequency of behaviors and mean behavior duration. The GLM is a mathematical model that will be used to measure the behavioral response variable with explanatory variables (the treatments on speaker schedules).

ETHOGRAM

The ethogram, or behavior matrix, provides data characterization of response variables. Listed here are examples of the behavior categories that will eventually lead to the formation of an Ashy Storm-Petrel ethogram. Categories are derived from behaviors observed at the study sites on Santa Cruz Island in 2010 (April – June). These will be used for analysis and identification of behaviors observed during future social attraction (speaker) treatments.

Agonistic

Single Approach (SA) – a subject approaches a conspecific.

Double Approach (DA) – two individuals approach each other simultaneously.

Pecking (PK) – subject shows aggression to a conspecific with the use of its bill.

Gaping (GP) – subject slowly edges towards a conspecific, often with its neck outstretched and its head either swaying from side to side and/or slowly bobbing up and down.

Lock & Tumble (LT) – one bird begins to peck at a conspecific, after which both individuals lock bills and tumble to a lower surface, off a rock or down a ledge.

Charge (CG) – subject charges toward a conspecific.

Pointing (PT) – subject is stationary, sitting with neck outstretched and points in the direction of a nearby conspecific.

Staring (ST) – subject is stationary and appears to be staring at a conspecific, this may include the subject periodically tilting its head to 75 degrees (‘star-gazing’), or bowing its head gently.

Visiting (VT) – two or more birds sit next to one another for a period of no more than 5 minutes.

Wing mounting (MT) – subject approaches conspecific in an upright position and flaps wings in response to the presence of a conspecific.

Locomotion

Hovering (HV) – subject is hovering inside the cave or cavern.

Walking (WK) – subject is walking.

Bowing-Walk (BW) – subject is bowing its head while walking. Subject appears curious or cautious.

Climbing (CM) - subject climbs a ledge, rock or wall without the use of its wings.

Wing Climbing (CW) – subject climbs a ledge, rock or wall with the use of its wings.

Stationary

Resting (RS) – subject is stationary and not indicating any directed interest in a conspecific or its surrounding environment.

Maintenance

Self-preening (SP) – subject manipulates its feathers with its beak; stretches or displays any other visible self-maintenance behavior.

Courtship Behaviors

Allo-preening (AP) – bird preens or manipulates the feathers of a conspecific.

Non-aggressive pecking (NP) – two individuals peck or lock beaks in a gentle, non-aggressive way.

Air to Ground Copulation (AG) – two birds circle and land, one then mounts the other. A brief period of sitting may occur where birds face the same direction. The female may wag her head at the male. The male may then grasp the female's bill and mount her. Birds may flutter about before mounting takes place.

Copulation (CP) – two individuals sit beside one another facing the same direction. One bird then mounts the other.

Nest Investigation

Nest Entry (NE) – subject completely enters a nest crevice.

Nest curious (NC) – subject appears to investigate a nest and may partially enter the nest, but does not enter the nest entirely.

NOTE: '-a' denotes that event took place in an artificial nest.

Chick

Any observations of older chicks (i.e., with adhering down) outside of nests prior to fledging (at times possibly with adults) will be carefully described. This behavior is suspected but has not been well documented.

Not Visible (NV)

(NV) - Category used if subject or subject's behavior is not visible during event.

Behavior recorded at Bat Cave (the natural nest site) is being examined where adults are entering and departing from nest sites visible in video footage in order to understand how natural nest site attendance behavior occurs. This includes duration and frequency of visitations, whether older chicks wander out of the nest, and whether any agonistic behavior occurs regularly between nearby nest sites. An advantage of filming in 2010 at Bat Cave is that a sample of behavior at a completely natural nest site is gained.

NOTE: the coding system below is used to catalogue observed behavior events. Any coded behavior that occurs as a direct interaction with the speaker system has the coding system changed so that an 's' appears on the record e.g. Pecking (PK-s). A code appended by an 's' denotes a subject's direct interaction with the speaker system. A code appended by an 'a' denotes a subject's direct interaction with an artificial nest.

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Appendix B.

Ethogram of the Ashy Storm-Petrel

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Introduction

In 2010, aspects of the behavior of the Ashy Storm-Petrel (*Oceanodroma homochroa*) at the breeding colony were described at Orizaba Rock and Bat Cave, Santa Cruz Island, southern California. This study was devised as an initial step for later evaluation of the success of a social attraction restoration project being conducted through the Montrose Settlements Restoration Program (MSRP 2005; McIver et al. 2011). Between April and September, behaviors of storm-petrels near a speaker broadcasting recorded vocalizations and at the entrances of artificial nest sites were recorded from 22:30-02:30 h using video cameras without visible light for about 7 days per month (until camera batteries were exhausted and batteries replaced). Behaviors (i.e., apparent actions and displays) of Ashy Storm-Petrels were described during review of video footage and compiled into an "ethogram" or catalog of behaviors along with other known behaviors from the literature. With this ethogram, most behaviors can be quantified from detailed review of video footage. This ethogram is presented below but additional explanation behind this ethogram and past efforts to describe behavior is provided first.

The main reason for constructing this ethogram was that behaviors of this species at the nesting colony were poorly known. The only previous study of the behavior of the Ashy Storm-Petrel was conducted at Southeast Farallon Island, central California, in 1964-65 (James-Veitch 1970). At this breeding colony, breeding habitats have been severely altered by human occupation for the past two centuries and most Ashy Storm-Petrels breed mainly in human-constructed rock walls and buildings (Ainley 1995; Carter et al. 2008). In addition, large numbers of avian predators (especially Western Gulls *Larus occidentalis* and Burrowing Owls *Athene cunicularia*) also occur at this island and an introduced mammal, the House Mouse (*Mus musculus*), also occurs and occasionally eats petrel eggs. This past study focused on general aspects of behavior and nesting biology and was conducted under very different circumstances than the Orizaba Rock study. Farallon observations were conducted between 17 March and 2 April 1964 and between 2 June and 9 September 1965. Individual nest chambers (n = 269), mostly in human-constructed rock walls, were examined opportunistically for a total of 816 hours. Many nests were first located by looking through cracks and holes in the floors and walls of old buildings, petrel odor, or observing a bird entering the nest site. In some cases, birds were observed to be nesting in empty sewage pipes where one end of the pipe had been blocked off. All observations were made by James-Veitch, often with the use of a light and without the aid of cameras. Field descriptions and sketches of the most

obvious displays were focused on as part of an initial description of the behavior of this species. Brief descriptions and sketches likely were composed in the field, with later expansion during formal write up.

James-Veitch's methods for observing Ashy Storm-Petrels also included many alterations of local nesting environments, including:

(1) *Light*: A lamp (unclear what type) was set up outside of the building so that birds could be easily observed;

(2) *Alteration of natural nest sites*: Upon discovery, natural nest sites often were altered for easier access with minimal disturbance to petrels, for example by creating a removable rock cover on nest chambers which could be used as an observation window into the nest. Once altered, petrel behavior was observed either through the removable rock cover, or through small holes in the nest chamber; and

(3) *Modification of artificial nest sites*: Human-constructed rock walls were adapted so that they contained empty chambers that would be accessible by Ashy Storm-Petrels. Some artificial habitat also was created in areas of the island where natural nest sites where not available.

By 1965, many of the nest chambers constructed in 1964 had deteriorated or collapsed due to bad weather in the previous winter. Some observation methods also were unsuccessful and resulted in nest desertion. It was unclear to what degree light and human presence affected behaviors, but it is likely that James-Veitch excluded any behaviors that he felt were highly affected.

In contrast to this Farallon study, the Orizaba Rock study in 2010 focused on:

(1) video recordings of behaviors at a colony where breeding habitats have not been greatly affected by human activities (except for lights from squid boats), no mammalian predators occur, and avian predator numbers are lower although Common Ravens (*Corvus corax*) and Western Gulls were present;

(2) obtaining standardized sample observations of Ashy Storm-Petrel behavior throughout the pre-breeding and breeding seasons;

(3) video recordings of behaviors using cameras without visible light and without human presence to prevent potential observer effects to behaviors;

(4) video recordings of behaviors near speakers and at the entrance to artificial nest sites to increase the numbers of birds detected, prevent observer effects to behaviors within nest sites, and examine how artificial nest sites are entered; and

(5) recording all clearly definable behaviors for later quantification purposes.

To produce a complete ethogram for the Ashy Storm-Petrel that included behaviors inside nest sites and near the entrances to natural and artificial nest sites and speakers, behaviors from Orizaba Rock, Bat Cave and Farallon studies were combined.

ASHY STORM-PETREL ETHOGRAM	
Behavior Category and Type	**Description**
CATEGORY A. INTER-BIRD BEHAVIORS	
(Type 1) Agonistic: defined as aggressive behaviors between two individuals	
(a) Peck	Bird A pecks with its bill.at bird B
(b) Gape	Bird A slowly edges towards bird B, often with its neck outstretched and its head either swaying from side to side and/or slowly bobbing up and down. Bill may be briefly agape.
(c) Fight	Bird A begins to peck at bird B, after which both individuals lock bills before they fly away or tumble to lower ground. Also observed by James-Veitch who noted that this may also occur with upraised wings and the body may be lifted off the ground as the bird shuffles or half runs and half flies at the other bird (see Charge).
(d) Charge	Charge – Bird A charges toward bird B. Usually bird B will fly off and leave the area. In some instances, bird A will also flap its wings at bird B.
(Type 2) Agonistic or Social: defined as aggressive or social behaviors between two individuals	
(a) Single Bird Approach	Bird A approaches bird B.
(b) Double Bird Approach	Bird A and bird B approach each other simultaneously.
(c) Stare	Bird A is stationary and observing the presence of bird B or a group of other birds. May include Bird A periodically tilting its head to about 75 degrees, or bowing its head gently. Also observed by James-Veitch and referred to as 'star gazing'
(d) Visiting	Two birds sit side-to-side for a short period. A bird may also 'visit' a nest and remain next to it for a short period. Also observed by James-Veitch.
(Type 3) Pairing: defined as behaviors between two individuals which appear to be related to pair interactions, pair bonding, mounting or copulation	
(a) Aerial Courting	Two birds circle in flight, sometimes with another joining in. Birds then land, chase one another, flutter and sometimes simply sit on the ground for a few moments before continuing to circle again. Not observed at OR or BC. Observed by James-Veitch.
(b) Non-aggressive peck	Two birds peck or lock beaks in a gentle, non-aggressive way. Not observed at OR or BC. Observed by James-Veitch both inside and outside of the nest and was attributed to pair-bonding behavior.
(c) Air-to-ground copulation	Two birds circle and land. A brief period of "side-to-side" sitting (with heads facing the same direction) may occur. The female may wag her head at the male. The male may then grasp the female's bill and mount her. Birds may flutter about before mounting takes place. (Not observed at OR or BC). James-Veitch determined the sex of at least one bird by capturing it immediately post-copulation and upon dissection discovered a fully-developed egg in the oviduct. Observed by James-Veitch.
(d) Copulation	Two birds sit side-to-side. One bird then mounts the other. Side-to-side

	sitting observed at OR and BC but without copulation. Also observed by James-Veitch with copulation.
(e) Nest Co-entering	Two birds entering a nest site together (i.e., natural or artificial sites). Observed at OR and BC. Also observed by James-Veitch

CATEGORY B. INDIVIDUAL BEHAVIORS	
(Type 4) Locomotive: defined as individual behaviors related only to movements in the air or on the ground at the colony without interaction with other individuals	
(a) Glide	A bird appears to glide in the wind. May be as a result of strong winds rushing through the cavern. Only observed at OR.
(b) Hover	Bird hovers for an extended period (not more than 3 seconds) inside the cave or cavern often fluttering just above the ground, repeatedly coming back to the same spot. Also observed by James-Veitch who thought that this could be a nest searching behavior if it occurs repeatedly.
(c) Searching	Birds 'search' among rocks and walls for a nest crevice or burrow, silent and frequently stopping to rest. Observed at OR and BC. Also observed by James-Veitch.
(d) Walk	Bird walks on its tarsi without clambering over substrate or nests.
(e) Climb	Bird climbs a gentle ledge, rock or wall without the use of its wings.
(f) Wing-climb	Bird climbs a ledge, rock or wall while vigorously flapping its wings. Usually occurs on cavern sides with steep gradient.
(g) Bowing-walk	Bird appears to bow its head slightly while walking. Subject appears curious or cautious. Similar to gape, but with no other visible birds present.
(h) Swoop	A circling bird swoops to within a foot or so of the ground and comes low enough to patter, flutter with dangling legs or hover briefly (< 3 seconds) above the ground but does not land. Also observed by James-Veitch
(Type 5) Nest Investigation: defined as individual behaviors related to nest sites	
(a) Nest entry	Bird completely enters a crevice and disappears from view.
(b) Nest curious	Bird appears to investigate a burrow or crevice entrance and may partially enter the nest site, but does not enter entirely. Or the bird may simply sit next to a nest site entrance.
(Type 6) Stationary: defined as individual behaviors on the ground without movement and without interaction with other individuals	
(a) Resting	Bird is stationary and still, not indicating any specific interaction with a conspecific or its surrounding environment.
(Type 7) Self-Maintenance: defined as individual behaviors related to plumage or skin maintenance (e.g., preening, rubbing, etc.). Not observed at OR and BC. Not observed or described by James-Veitch. These behaviors may occur inside nest sites or at sea.	

CATEGORY C. SPEAKER & ARTIFICIAL NEST SITE INTERACTIONS	
(Type 8) Speaker: defined as associated with the speaker	
(a) Speaker interaction	Bird directly interacts with the speaker by approaching it and flapping its wings either on or very close to the speaker. Bird remains at the speaker for a short period before either wandering off or flying away.
(Type 9) Artificial Nest: defined as associated with artificial nest sites	
(a) Nest entry-A	Bird completely enters an artificial nest and disappears from view.
(b) Nest curious-A	Bird appears to investigate the entrance of an artificial nest and may

	partially enter the nest, but does not enter entirely.

Behavior Images

Below, still images of various Ashy Storm-Petrel behaviors are presented. All images were obtained with remote video camera systems deployed at Orizaba Rock and Bat Cave, Santa Cruz Island, California, in 2010. Date and time stamps occur in each image. All photos were selected by L. Halpin.

Figure B-1. Ashy Storm-Petrel showing 'Speaker Interaction' behavior (C8a) in the lower cavern at Orizaba Rock, 12 May 2010.

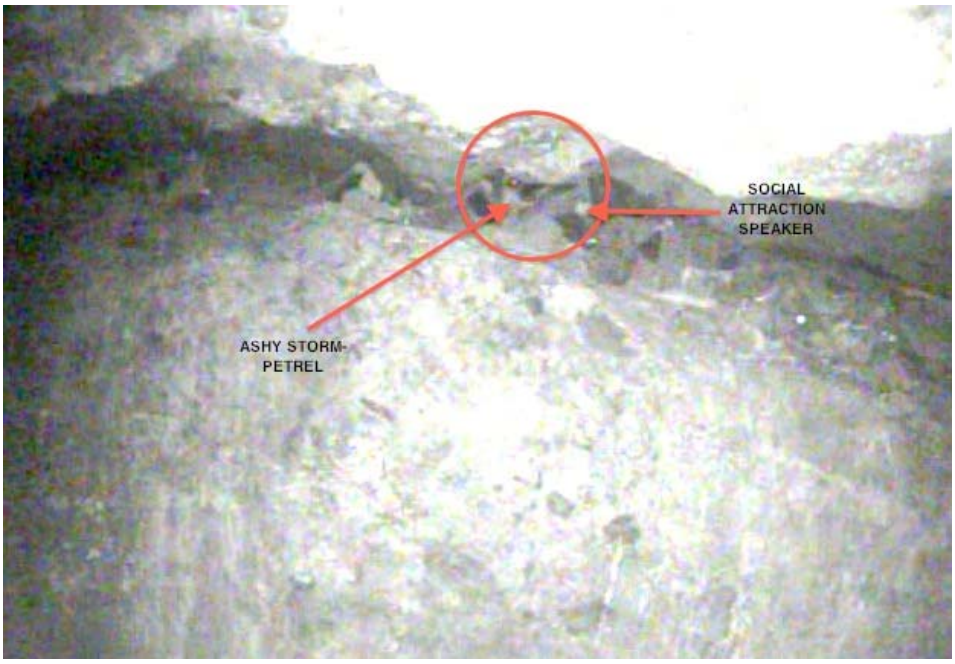

Figure B-2. Ashy Storm-Petrel showing 'Speaker Curious' behavior (C8b) in the upper west cavern at Orizaba Rock.

Figure B-3. Ashy Storm-Petrel showing ‘Swoop’ behavior (B4h) in the upper west cavern at Orizaba Rock, 16 April 2010.

Figure B-4. Ashy Storm-Petrel showing ‘nest entry behavior’ (B5a) at Bat Cave, 16 August 2010. This is the same nest site as shown in Figure B-5.

Figure B-5. Ashy Storm-Petrel showing 'nest curious' behavior (B5b) above a known nest site at Bat Cave, 14 May 2010. This is the same nest site as shown in Figure B-4.

Literature Cited

Ainley, D.G. 1995. Ashy Storm-Petrel (*Oceanodroma homochroa*). In: A. Poole and F. Gill, eds. The Birds of North America, No. 185. The Academy of Natural Sciences, Philadelphia, Pennsylvania, and The American Ornithologists' Union, Washington, D.C.

Carter, H.R., W.R. McIver, and G.J. McChesney. 2008. Ashy Storm-Petrel (*Oceanodroma homochroa*). Pages 117-124 In: W.D. Shuford, and T. Gardali (eds.). California Bird Species of Special Concern: a ranked assessment of species, subspecies, and distinct populations of birds of immediate conservation concern in California. Studies of Western Birds 1. Western Field Ornithologists, Camarillo, California, and California Department of Fish and Game, Sacramento, California.

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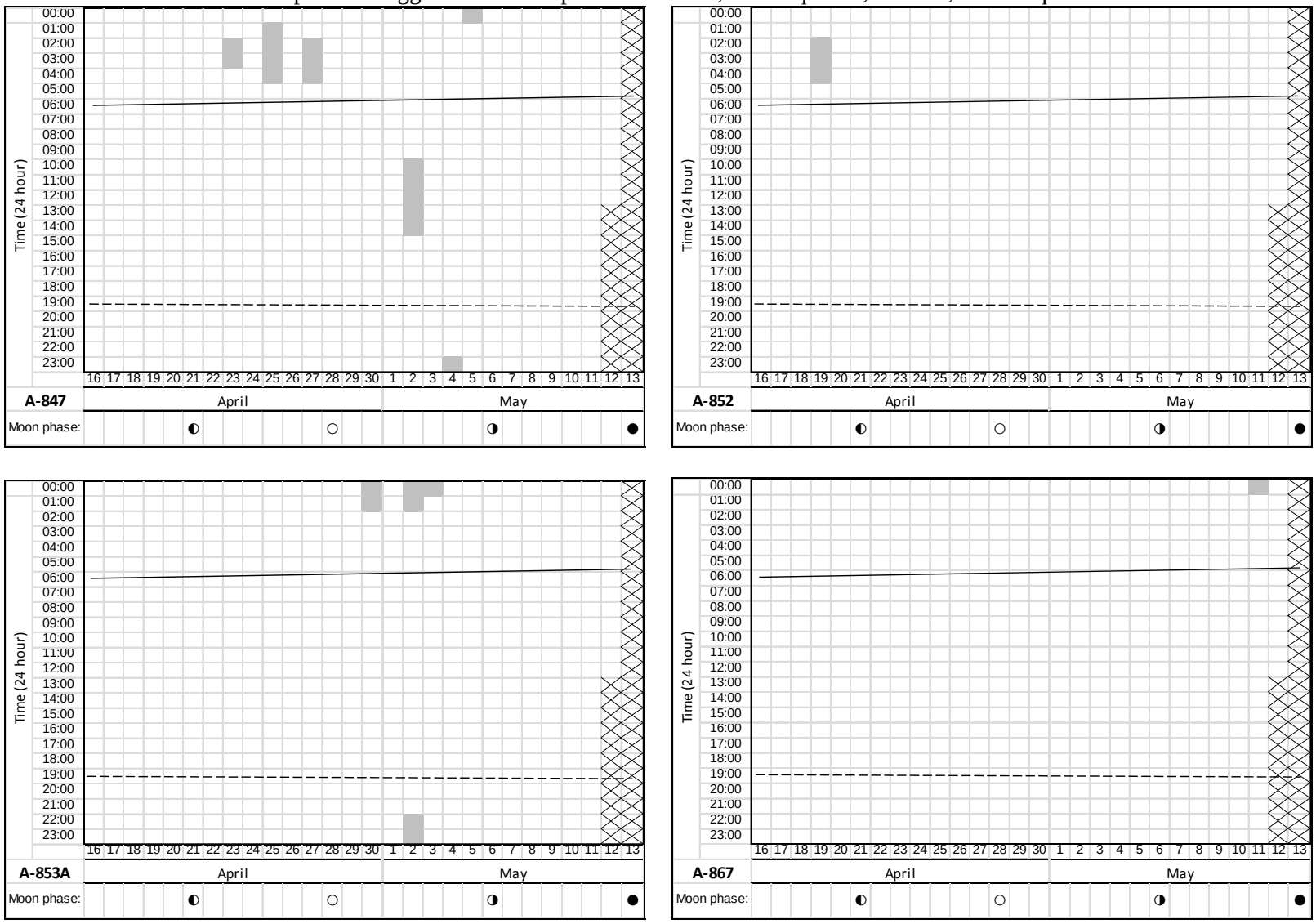
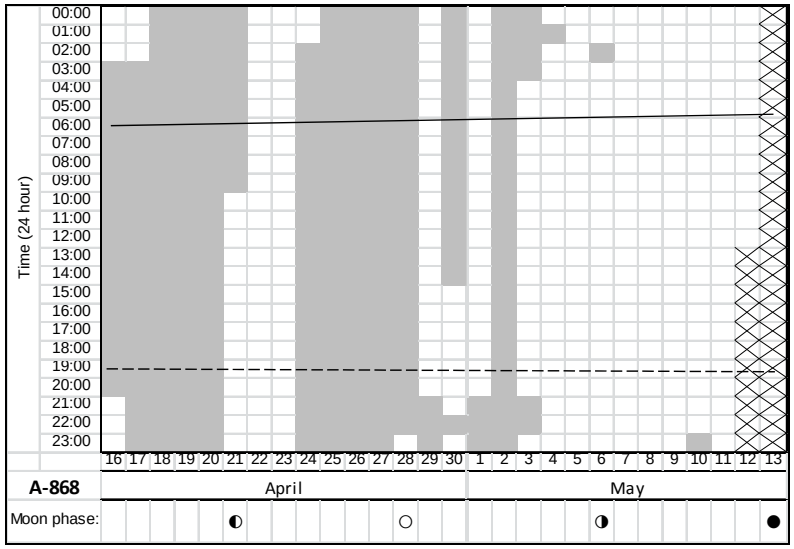
McIver, W.R., A.L. Harvey, H.R. Carter, and L.R. Halpin. 2011. Monitoring and restoration of Ashy Storm-Petrels at Santa Cruz Island, California, in 2010. Unpublished report, U.S. Fish and Wildlife Service, Arcata, California; Channel Islands National Park, Ventura, California; and Carter Biological Consulting, Victoria, British Columbia. 40 p.

Appendix C-1. Hourly visitation and attendance patterns of Ashy Storm-Petrels at six artificial nest sites on Orizaba Rock between 16 April and 12 May 2010, as measured by iButton temperature loggers.. Presence of a storm petrel in a specific is indicated by a gray box. Solid lines show sunrise times; dashed lines show sunset times. Tag number for each artificial nest site shown at lower left of each graph. Crossed hours indicate no temperature logger data. Moon phases: ● = new, ◐ = 1st quarter, ○ = full, ◑ = 3rd quarter.

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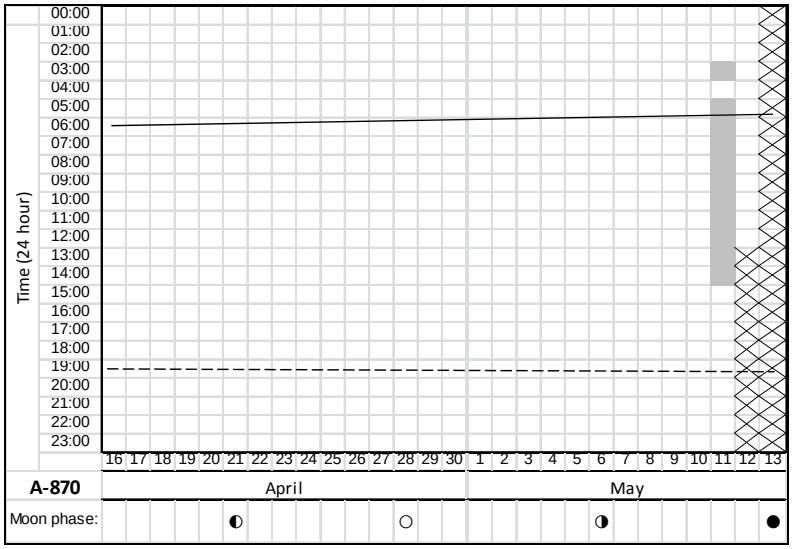
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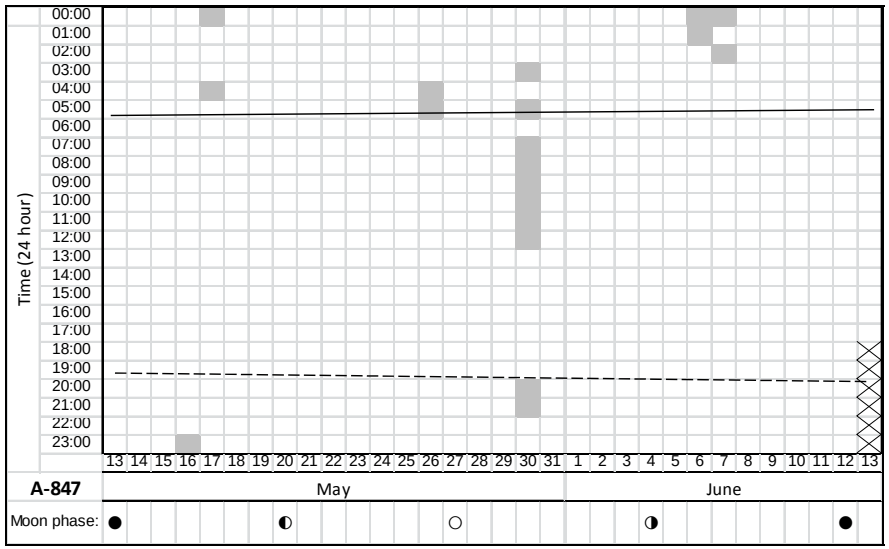
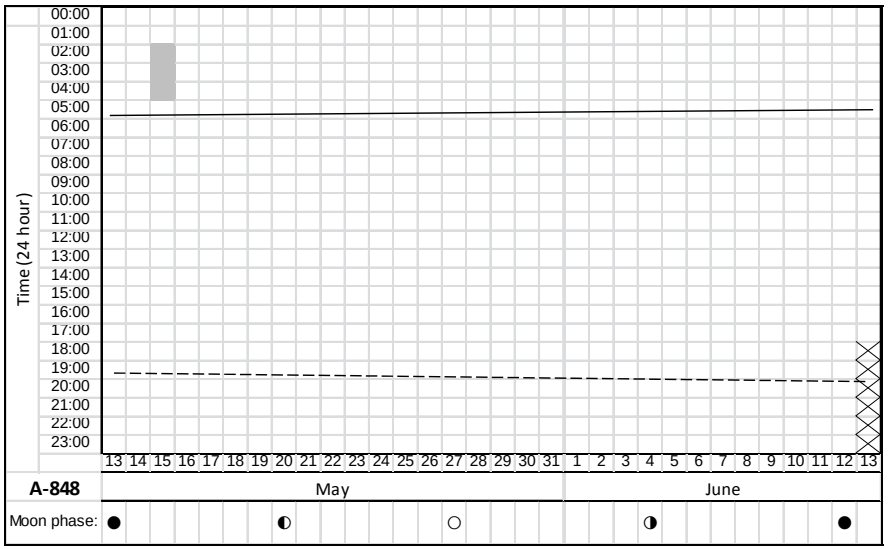
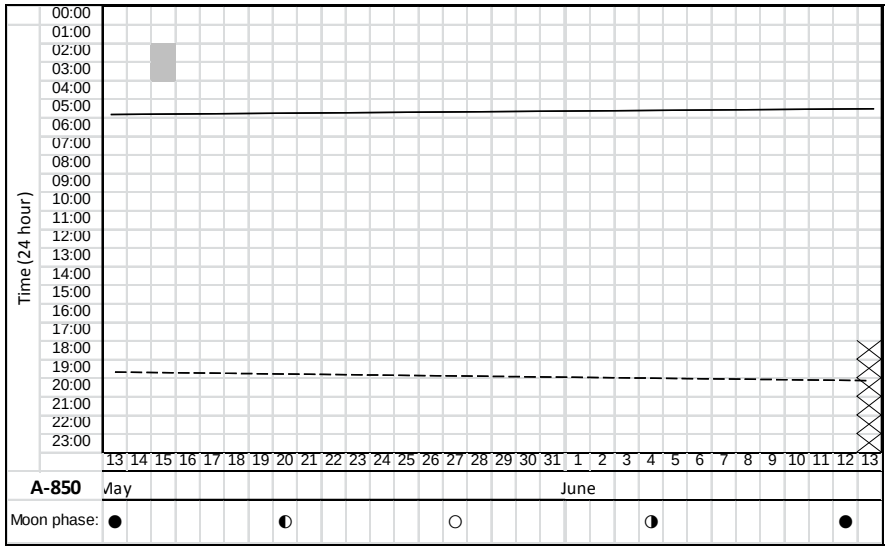
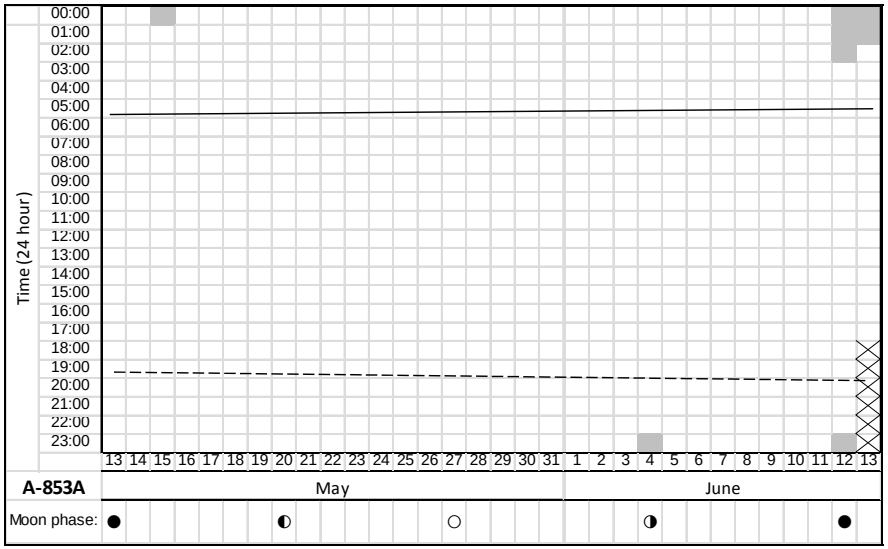
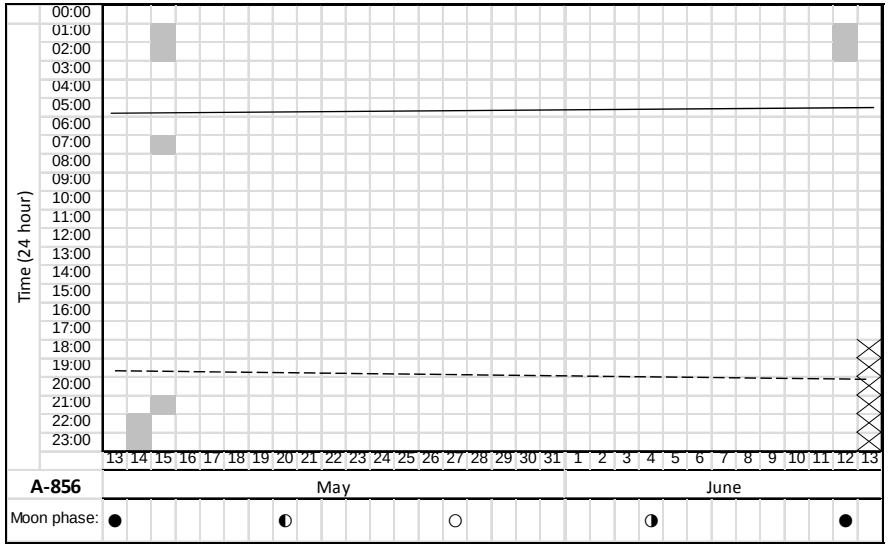
Appendix C-2. Hourly visitation and attendance patterns of Ashy Storm-Petrels at twelve artificial nest sites on Orizaba Rock between 13 May and 13 June 2010, as measured by iButton temperature loggers.. Appendix format described under Appendix C-1.







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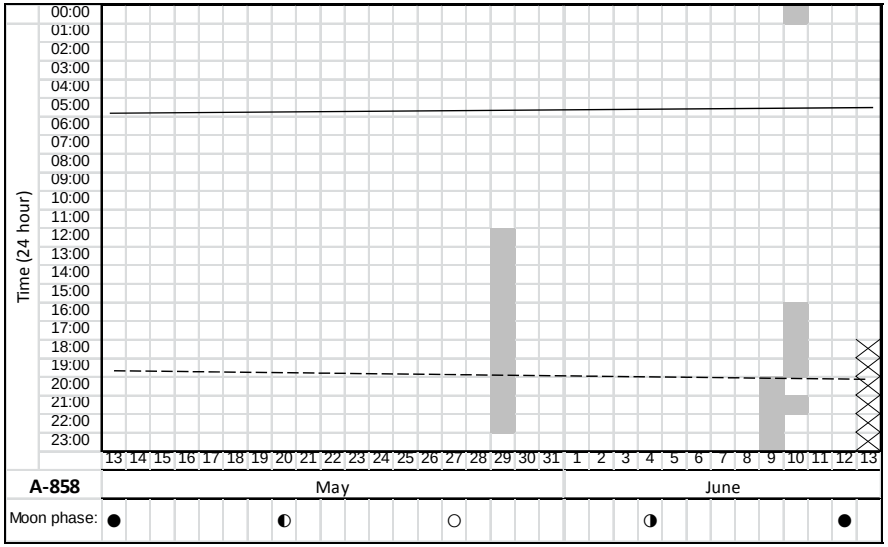
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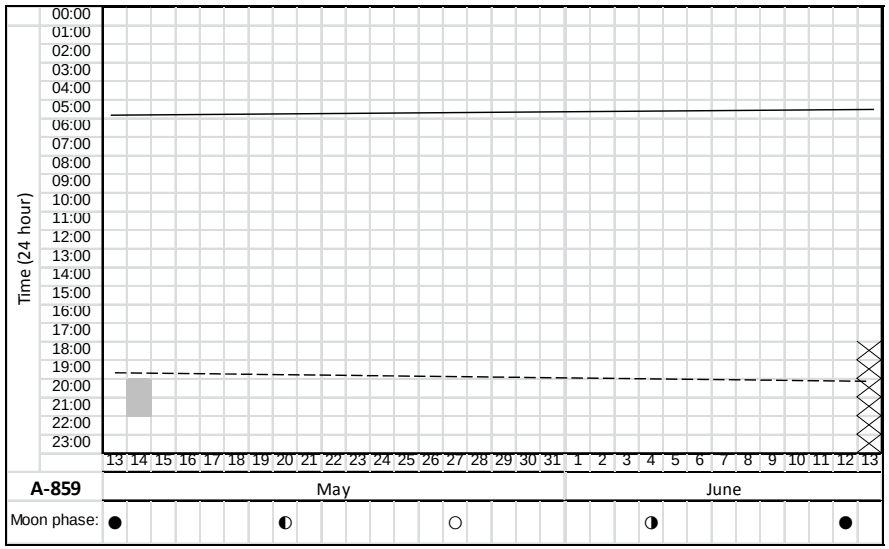
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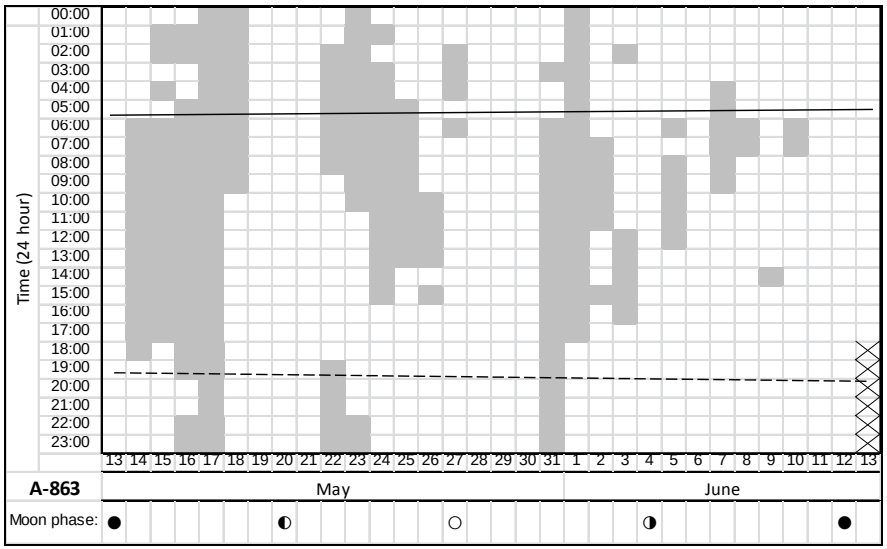
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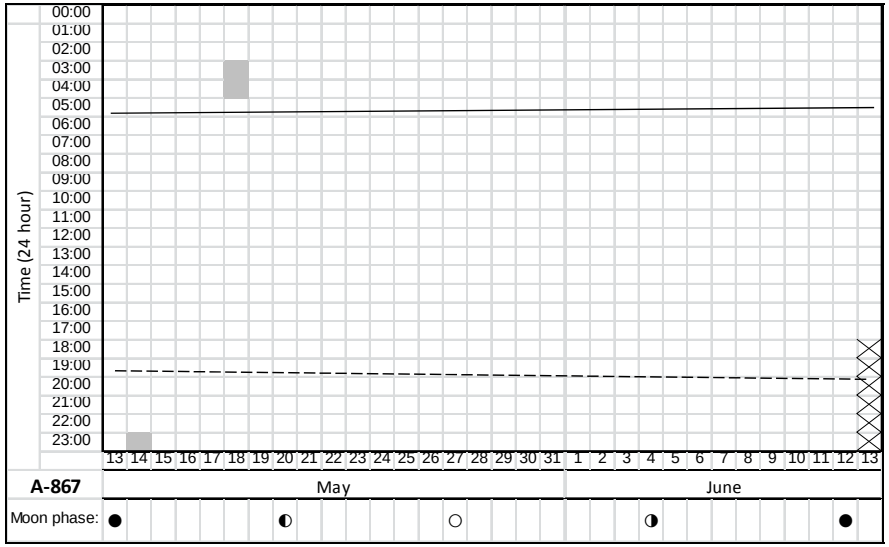
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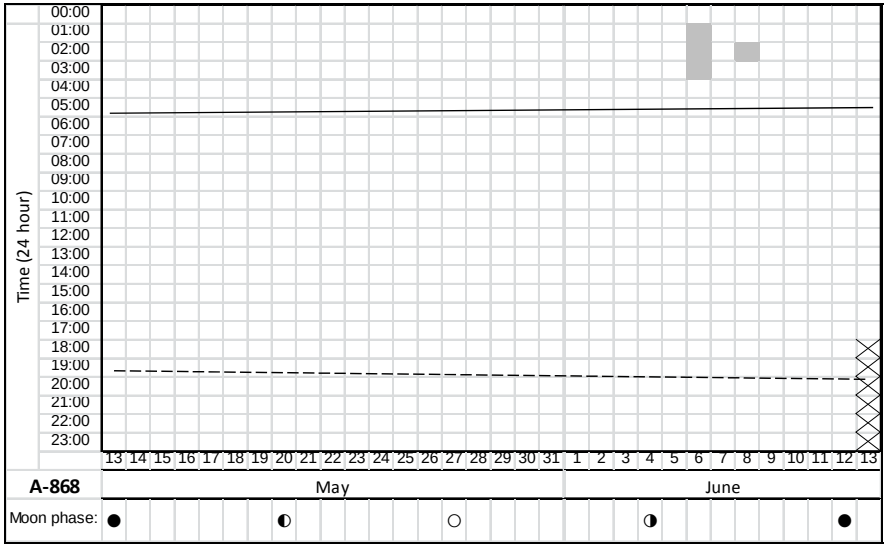
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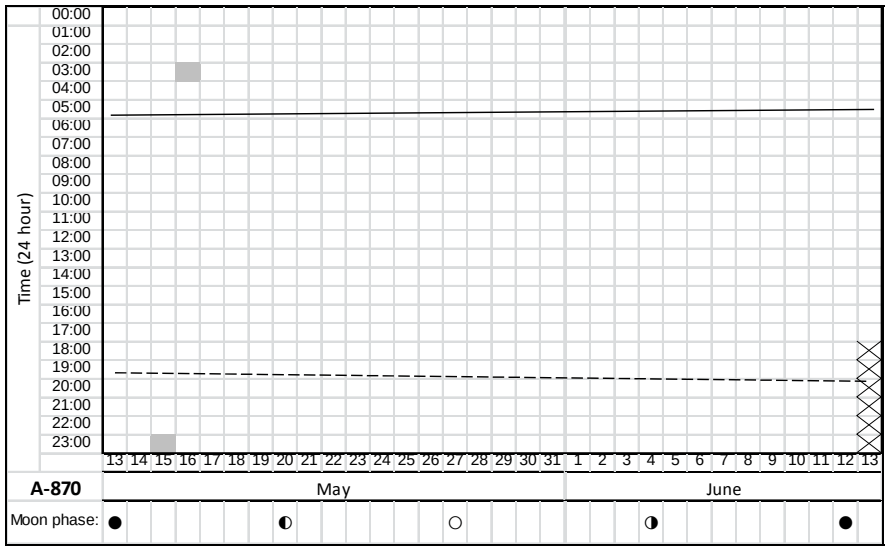
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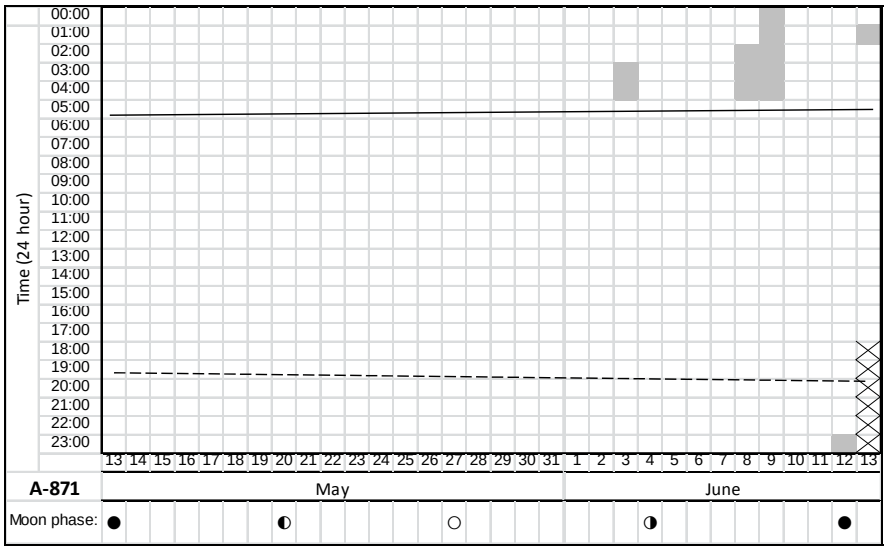
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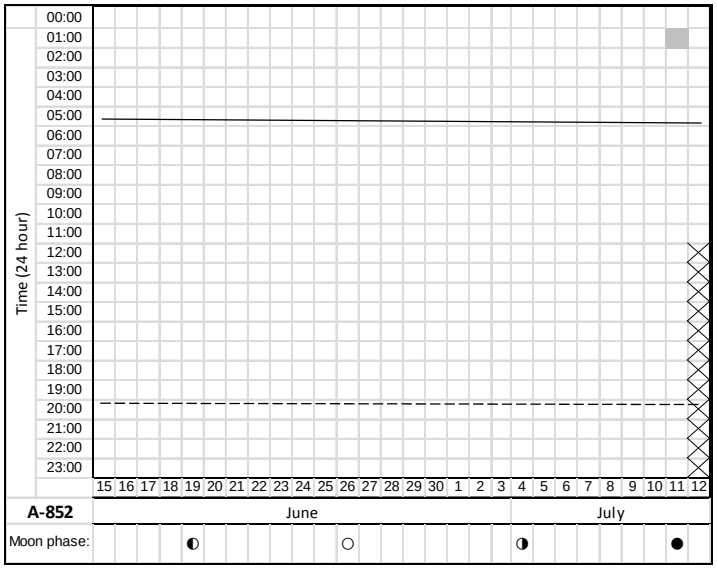
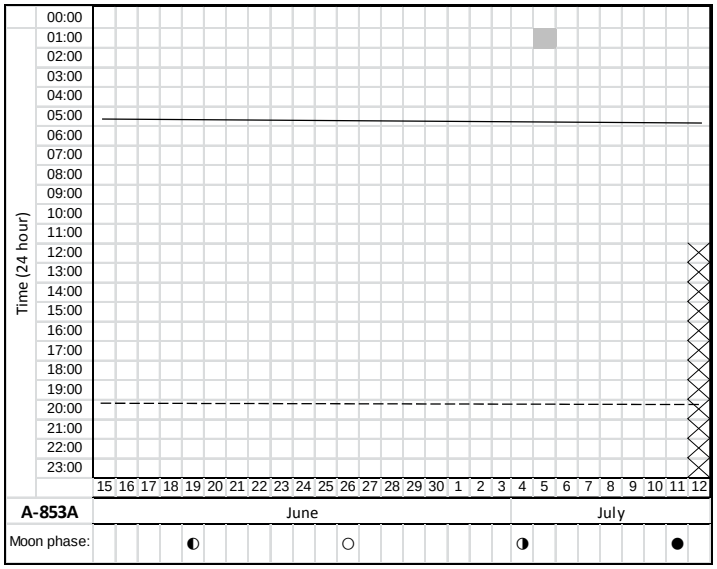
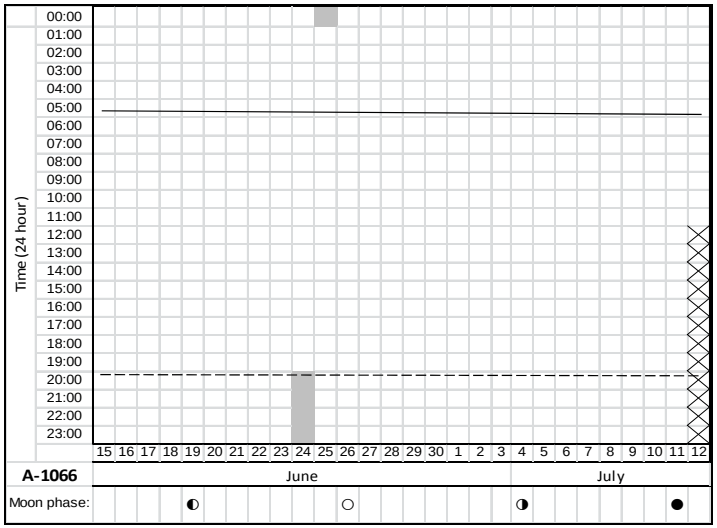
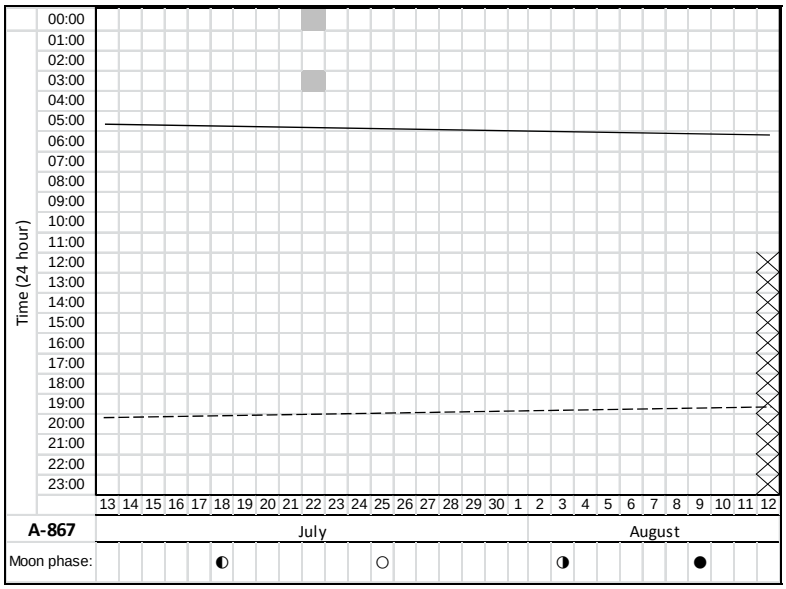
Appendix C-3. Hourly visitation and attendance patterns of Ashy Storm-Petrels at three artificial nest sites on Orizaba Rock between 15 June and 12 July 2010, as measured by iButton temperature loggers. Appendix format described under Appendix C-1.







Appendix C-4. Hourly visitation and attendance patterns of Ashy Storm-Petrels at artificial nest site A-867 at Orizaba Rock between 13 July and 12 August 2010, as measured by iButton temperature loggers. Appendix format described under Appendix C-1.



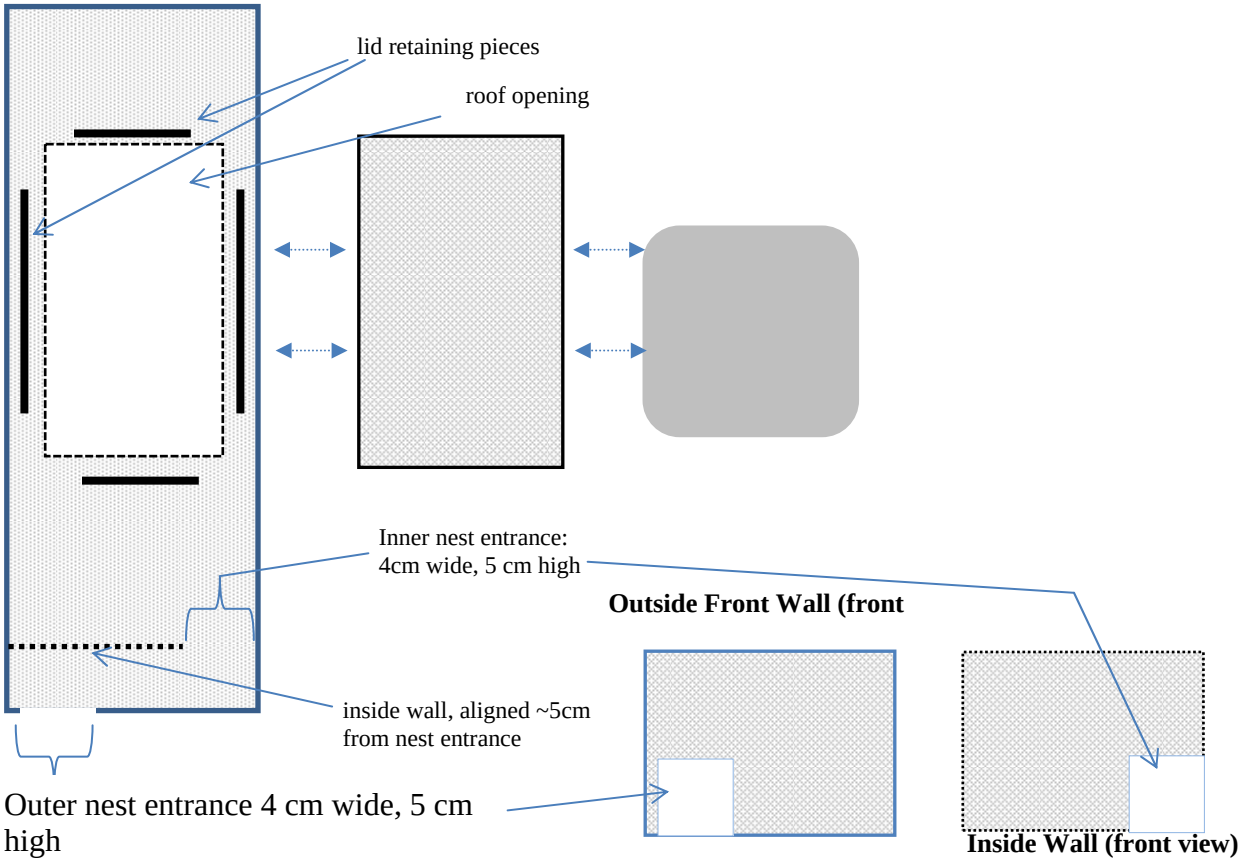
Appendix D. PIT-tag identification numbers of 53 Ashy Storm-Petrels (50 chicks, 3 adults) tagged at Santa Cruz Island, California, in 2010. Abbreviations for locations: BC = Bat Cave, CBE = Cave of the Birds' Eggs, DR = Diablo Rocks, DSB = Dry Sandy Beach Cave, OR = Orizaba Rock.

Location	Date banded	PIT-TAG ID NUMBER	Nest Tag Number	Life Stage
BC	8/13/2010	985121021087891	818	chick
BC	8/13/2010	985121021129711	1074	chick
BC	8/13/2010	985121021133272	1041A.	chick
BC	8/13/2010	985121021144023	1038	chick
BC	8/13/2010	985121021145560	1003	chick
BC	9/16/2010	985121021089123	733	chick
BC	9/16/2010	985121021101811	819	chick
BC	9/16/2010	985121021113982	825	chick
BC	9/16/2010	985121021114404	1046	chick
BC	9/16/2010	985121021116839	833	chick
BC	9/16/2010	985121021117983	828	chick
BC	9/16/2010	985121021118964	802	chick
BC	9/16/2010	985121021130198	913	chick
BC	9/16/2010	985121021133147	1045	chick
BC	9/16/2010	985121021133376	1017	chick
BC	9/16/2010	985121021142778	836	chick
BC	9/16/2010	985121021143642	1035	chick
BC	9/16/2010	985121021144695	834	chick
BC	9/16/2010	985121021145643	817	chick
BC	9/16/2010	985121021146529	1019	chick
BC	9/16/2010	985121021146955	1008	chick
BC	9/16/2010	985121021155720	823	chick
BC	10/12/2010	985121021127870	837	chick
BC	10/12/2010	985121021145735	1100	chick
CBE	9/15/2010	985121021085115	718	chick
CBE	9/15/2010	985121021113570	769	chick
CBE	9/15/2010	985121021132366	829	chick
CBE	9/15/2010	985121021145492	719	chick
CBE	9/15/2010	985121021146776	942	chick
CBE	10/12/2010	985121021128237	1020	chick
DSB	10/12/2010	985121021087269	1061	chick
DSB	10/12/2010	985121021103664	1077	chick
DSB	10/12/2010	985121021127565	1054	chick
DSB	10/12/2010	985121021144842	710	chick
DSB	10/12/2010	985121021157040	1078	chick

Location	Date banded	PIT-TAG ID NUMBER	Nest Tag Number	Life Stage
DSB	10/12/2010	985121021157549	1075	chick
DSB	10/12/2010	985121021158071	1065	chick
DSB	12/2/2010	985121021088395	1083	chick
DSB	12/2/2010	985121021129442	1080	chick
DSB	12/2/2010	985121021131592	1076	chick
DSB	12/2/2010	985121021141870	1057	chick
DSB	12/2/2010	985121021145220	796	chick
OR	8/12/2010	985121021117822	1082	chick
OR	8/12/2010	985121021141048	A-863.	chick
OR	9/15/2010	985121021086401	832	chick
OR	9/15/2010	985121021114084	483	chick
OR	9/16/2010	985121021142454	748	chick
OR	10/12/2010	985121021130875	33	chick
OR	10/12/2010	985121021142934	unmarked site	chick
OR	11/16/2010	985121021145172	1011A.	chick
DR	4/16/2010	985121021129534	-	adult
DR	4/16/2010	985121021142929	-	adult
DR	4/16/2010	985121021132647	-	adult

Appendix E. Recommended design for protective artificial site for Ashy Storm-Petrel at Cavern Point Cove Caves, Santa Cruz Island, California (prepared by W.R. McIver).

Artificial Nest – Top View:



Each nest would consist of the following ceramic pieces: floor piece; 2 side pieces; roof piece with a rectangular opening; inside wall w/ an entrance opening (4cm W x 5cm H); front outside wall w/ an entrance opening (4cm W x 5cm H); back wall; and lid. In addition, 4 "lid ridges" (long thin rectangular metal pieces) would be epoxied to the top of nest to keep the lid from sliding, and 1 brick paver, 15cm^2, would be placed on top of the lid, to secure it. After firing (high temperature firing), each nest would be assembled by epoxying the pieces together.

Dimensions (cm) of clay/ceramic pieces

pre-firing	width	length	*post-firing*	width	length
floor	15.6	35.6	floor	14	32
roof	15.6	35.6	roof	14	32
lid	13.3	17.8	lid	12	16
	height	length		height	length
side (2)	13.3	33.3	side (2)	12	30
	width	height		height	length
back	13.3	13.3	back	12	12
front	13.3	13.3	front*	12	12
inside wall	13.3	13.3	inside wall*	12	12

* w/ entrance cut at 4cm W x 5cm H