# Reproductive Status Assessments and Restoration Recommendations for Ashy Storm-Petrels, Scripps's Murrelets, and Cassin's Auklets breeding on Anacapa Island, Channel Islands National Park

## Chapter 1: Ashy Storm-Petrel, Scripps's Murrelet, and Cassin's Auklet reproductive status assessments and restoration recommendations in 2011-2012

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## Chapter 2: Passive acoustic surveys for Ashy Storm-Petrel vocal activity on Anacapa Island in 2011 and 2012

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**Final Report**

**1 November 2013**

Suggested Citations:

Chapter 1: Harvey, A. L., D.M. Mazurkiewicz, M. McKown, K.W. Barnes, M.W. Parker, and S.J. Kim. 2013. Ashy Storm-Petrel, Scripps's Murrelet, and Cassin's Auklet reproductive status assessments and restoration recommendations in 2011-2012. Unpublished report, California Institute of Environmental Studies. 55 pages.

Chapter 2: McKown, M.W., B. Tershy, and D. Croll. 2013. Passive acoustic surveys for Ashy Storm-Petrel vocal activity on Anacapa Island in 2011 and 2012. Unpublished report, Conservation Metrics Inc. 14 pages.

## EXECUTIVE SUMMARY

- We conducted a two year study at Anacapa Island to assess current breeding distribution of Ashy-Storm Petrels (*Oceanodroma homochroa;* ASSP), Cassin's Auklets (*Ptychoramphus aleuticus;* CAAU), and Scripps's Murrelets (*Synthliboramphus scrippsi;* SCMU).

- The overall goal of the project was to develop restoration recommendations based on the current reproductive status of the three species.

- We designed a study intended to (1) build on extensive SCMU surveys conducted before and after the rat eradication project of 2001-2002 to assess whether colony expansion was occurring; (2) document the current extent of CAAU nesting, and (3) determine the nesting status of the ASSP on Anacapa Island.

- We used several different survey methods to meet study goals, including traditional habitat and shoreline searches, passive recording devices, mist netting, cave searches, and nocturnal captures.

- Scripps's Murrelets showed a continued increase in reproductive success at monitored sea caves, but expansion to other areas was limited.

- Cassin's Auklets showed a slight increase in total nesting numbers from previous surveys.

- We discovered the first Ashy Storm-Petrel nest ever documented on Anacapa Island.

- While these small increases are encouraging, colony sizes for all three species appear to remain at very low levels with respect to available habitat.

- Recommendations include designing a multiple-species monitoring program for seabird species on Anacapa in addition to the three species under study, including: California Brown Pelican, Brant's, Double-crested, and Pelagic Cormorants, Pigeon Guillemots, and Black Oystercatchers.

- We conclude that all three species would benefit from additional restoration actions to decrease impacts of stochastic events by increasing colony sizes at this important breeding location.

# Chapter One: Ashy Storm-Petrel, Scripps's Murrelet and Cassin's Auklet reproductive status assessments and restoration recommendations, 2011-2012

## INTRODUCTION

The five islands that comprise the Channel Islands National Park (CINP) provide critical breeding habitat for twelve species of breeding seabirds. The smallest islands of the Park, which include Santa Barbara Island (SBI), Anacapa (ANI), and Prince Island (located offshore San Miguel Island), are particularly important seabird colony locations due in part to the lack of large native mammalian land predators such as the Island Spotted Skunk (*Spilogale gracilis*) and Island Fox (*Urocyon littoralis*) which occur on other islands. The largely inaccessible sea cave habitat, along with the offshore rocks and sea stacks associated with the islands, have also functioned as refuges for seabirds impacted by a variety of introduced land predators such as feral cats (*Felis catus*) and Black Rats (*Rattus rattus*).

In addition to being protected as a National Park, several major restoration projects have been implemented with the goal of improving breeding conditions for seabirds. For example, the eradication of Black Rats from Anacapa Island was completed in 2001-2002 to benefit seabird species, such as the Scripps's Murrelet (*Synthliboramphus scrippsi*, SCMU), that were most heavily impacted by rat predation (Howald et al. 2009). Annual nest monitoring for the SCMU found that reproduction quickly improved thereafter (Whitworth et al. 2008, 2009a, 2011a, 2013). However, significant colony expansion from habitats (primarily sea caves) that had provided refuges for the remaining population was not apparent, and the status of other small nocturnal crevice-nesting species was not well known. In particular, the Ashy Storm-Petrel (*Oceanodroma homochroa*, ASSP) had never been documented as a breeding species on Anacapa, but previous researchers suggested that breeding had probably occurred there historically (McChesney et al. 1998, Carter and Whitworth 2013). Additionally, some evidence of Cassin's Auklet (*Ptychoramphus aleuticus*, CAAU) nesting expansion subsequent to the rat eradication was noted during SCMU monitoring, but dedicated projects to determine nesting activity during the breeding seasons for both the CAAU and ASSP had not been conducted after the rat eradication until the current study (Whitworth et al. 2011).

The combined breeding seasons for the three species under study overlap, spanning the entire calendar year. CAAU are the earliest breeders of the three species, with nesting initiation (prospecting, burrow excavation, and egg-laying) in the Channel Islands typically occurring in December to March (Adams 2008). The CAAU incubation and chick provisioning periods for first clutches at nearby Scorpion Rock (offshore Santa Cruz Island; SCI) and Prince Island (offshore San Miguel Island) span approximately 90 days; second clutches are common in years with high prey availability (Adams et al. 2004, Adams et.al 2009 ). The CAAU nesting season can therefore last a total of nearly six months in years of high primary productivity (Adams et al. 2004).

In contrast, SCMU nests are typically active for just 45 days; chicks depart the nest at approximately two days after hatching, and the chick fledging period is completed at sea (Murray et al. 1983). SCMU nesting initiation is typically quite predictable, occurring in late February to early March at both Anacapa and Santa Barbara Islands; in most years nesting is completed by June (Murray et al. 1983, Harvey and Barnes 2009, Harvey et al. 2012, 2013, Whitworth et al. 2013). Conversely, the ASSP nesting season is much more prolonged; adults begin prospecting at the Channel Islands colonies at least as early as February; colony numbers (active nests) usually peak in July, and in some years the latest fledging (at nearby SCI) occurs in December (Carter et al. 2008, McIver et al. 2008, 2009, 2010, 2011, 2013). This study therefore was designed to gather information with which to assess reproductive activity during a study period that would be sufficient to capture breeding information for each of the three species.

In 2011, we began a two-year project to provide an updated status assessment of ASSP, CAAU and SCMU on the three Anacapa islets (East, Middle and West) as part of the Montrose Settlements Restoration Program (MSRP 2005, 2012). The goals of this study were to (1) build on extensive SCMU surveys conducted before and after the rat eradication project to assess whether colony expansion was occurring; (2) document the current extent of CAAU nesting, and (3) determine the nesting status of the ASSP on Anacapa Island. This report presents results of surveys conducted at Anacapa Island in 2011-2012 and provides restoration and monitoring recommendations resulting from our findings.

**METHODS**

Our study location was Anacapa Island, located approximately 23 km offshore Ventura, CA. The three islets (East, Middle, and West; Figure 1) of Anacapa have a total land area of about 700 acres, with a combined shoreline length of approximately 31 km (Terrapoint 2010). East Anacapa Island (EAI) hosts CINP residences, visitor center, and infrastructure, and is a popular tourist destination. Landing by the public is permitted on the shorelines of all islets, but prohibited on offshore rocks; the upper areas of Middle and West islands (MAI and WAI, respectively) are closed to access without a research permit.

We used a variety of survey methods to assess the status of CAAU, ASSP, and SCMU over seven months in each calendar year: plot-based nest monitoring and at-sea capture and banding for SCMU, mist-netting and acoustic recording units (ARU) for ASSP (see Chapter 2 for results of the latter technique), and extended (outside-plot) habitat searches for all three species. We completed a total of 22 and 21 boat-based survey days in 2011 and 2012, respectively (Tables 1, 2).

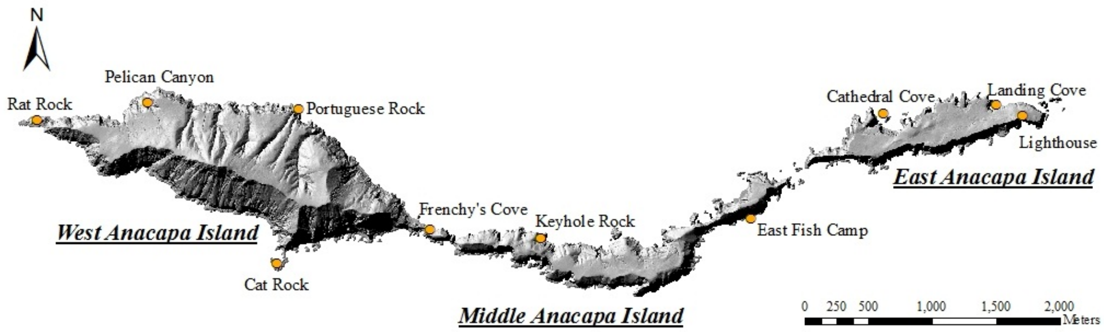


**Figure 1. Overview map of the three islets comprising Anacapa Island.**

**Table 1. General survey information for the Anacapa project in 2011.**

| Survey Number | Dates | Surveys Conducted |
|---|---|---|
| 1 | 27-28 March 2011 | SCMU plot monitoring |
| 2 | 4 April 2011 | SCMU plot monitoring |
| 3 | 11 April 2011 | SCMU plot monitoring |
| 4 | 1 May 2011 | SCMU plot monitoring |
| 5 | 7 May 2011 | SCMU plot monitoring |
| 6 | 25 May 2011 | SCMU plot monitoring, ARU deployments, habitat searches |
| 7 | 6 June 2011 | SCMU plot monitoring, ARU deployments, habitat searches |
| 8 | 24-27 June 2011 | SCMU plot monitoring, ARU deployments, habitat searches, mist-netting |
| 9 | 26-29 July 2011 | SCMU plot monitoring, ARU deployments, habitat searches, mist-netting |
| 10 | 25-27 August 2011 | ARU deployments, habitat searches |
| 11 | 26-28 September 2011 | ARU deployments, habitat searches |

**Table 2. General survey information for the Anacapa project in 2012.**

| Survey Number | Dates | Surveys Conducted |
|---|---|---|
| 1 | 4-5 March 2012 | SCMU plot monitoring, ARU deployments |
| 2 | 12 March 2012 | SCMU plot monitoring |
| 3 | 22-24 March 2012 | SCMU plot monitoring, ARU deploy, habitat search |
| 4 | 7 Apr 2012 | SCMU plot monitoring |
| 5 | 19-21 April 2012 | SCMU plot monitoring, ARU deploy, habitat search, dipnet captures |
| 6 | 30 April 2012 | SCMU plot monitoring |
| 7 | 8 May 2012 | SCMU plot monitoring |
| 8 | 27-29 May 2012 | SCMU plot monitoring, ARU deployments, habitat search, dipnet captures |
| 9 | 8 June 2012 | SCMU plot monitoring |
| 10 | 16-18 June 2012 | SCMU plot monitoring, ARU deployments, habitat search, mistnetting |
| 11 | 14 July 2012 | SCMU plot monitoring, ARU pickup, habitat search |
| 12 | 30 October 2012 | ARU pickup, habitat search |

**SCMU reproductive monitoring.**

Methods for SCMU nest monitoring followed those in Whitworth et al. (2011), Harvey and Barnes (2009), and Harvey et al. (2012, 2013). Briefly, shoreline and sea cave monitoring locations were accessed using an inflatable Zodiac® launched from a support vessel. Nest contents were examined briefly using handheld flashlights. Adult murrelets were not handled while on the nest; unattended eggs were examined and numbered using a permanent marker. Eggshell fragments were removed if accessible to assist in nest fate determinations; egg shells were bagged individually and are archived in CINP storage to allow for possible future genetic analyses (see Whitworth et al. 2011b, Harvey et al. 2013 for discussion). To the extent possible, we retained individual site numbers used in previous studies.

Active (also "occupied") murrelet sites were defined as those with evidence of egg-laying (i.e. eggs seen, chicks seen, or adult in nest during daylight hours). We reported nest initiation as the date the first egg of the clutch was laid, because SCMU clutch completion (i.e. date second egg is laid) typically occurs approximately eight days after the first egg is laid (range 5-12 days; Murray et al. 1983). Egg-laying dates were determined either by direct observation or by estimating date based on published mean periods between clutch initiation, completion, incubation, and hatching (Murray et al. 1983).

We assumed that SCMU are able to lay a maximum of two eggs per clutch (see Harvey et al. 2012, 2013 and references therein for discussion of multiple clutches within discrete nest sites); three or more eggs within a discrete nest site therefore were identified as part of a separate clutch (also "attempt"). In the event that a clutch was comprised of only one (observed) egg, we assumed that sequential egg-laying represented a separate clutch if: a) one additional egg was subsequently laid after published periods of egg neglect had elapsed (see Murray et al. 1983), *or* b) if a concurrent or later clutch of 2 eggs was laid. In the event that more than 4 eggs were laid in a discrete nest site, the same logic was employed to identify the ultimate number of clutches over the course of the season. We reported one measure of reproductive success: "clutch success" (CS), defined as those clutches where at least one egg ultimately hatched. The CS statistic is analogous to the "hatching success" statistic reported in previous Anacapa breeding studies; see Harvey et al. (2012, 2013) for discussion. Eggs and clutches with unknown fates were excluded from calculations.

We selected 10 of the 13 locations that were regularly monitored in previous years by Whitworth et al. (2013) to monitor SCMU reproductive success: Refuge Cave, Lava Bench #1 Cave, Lava Bench #2 Cave, Respiring Chimney Cave, Rockfall Cove, Lonely at the Top Cave, Pinnacle Cave, Moss Cave, Aerie Cave, and Keyhole Cave (Figure 2). The remaining three locations previously monitored by Whitworth et al. (2012 and references therein): were visited early in the season in 2011 but excluded from later surveys (Landing Cove: 27 March, Confusion Cave: 4 April, and Cat Rock: 4 April).

We used sea cave names identified by Bunnell et al. (1993). Surveys were designed to capture general trends rather than fine-scale information, and so were scheduled every two weeks beginning in mid-March as opposed to more frequent nest checks as in previous years. As in most years, survey intervals varied due to weather constraints and not all locations could be visited during each monitoring trip.

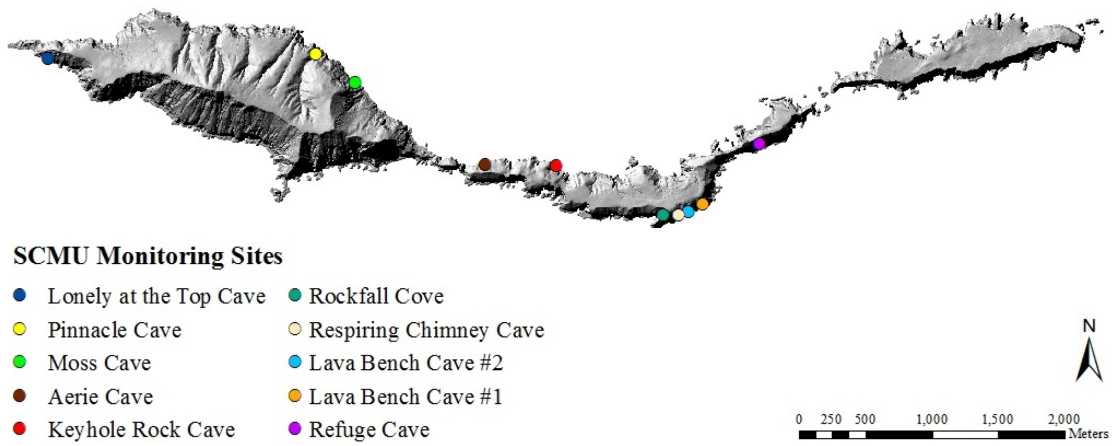


**Figure 2. Locations of the ten plot-based monitoring locations used to evaluate Scripps's Murrelet reproductive success in 2011 and 2012.**

**SCMU capture and banding.** Methodology for nightlighting captures is detailed in Whitworth et al. (1997). Briefly, a team of three personnel (driver, spotlight handler, and net handler) captured birds from an inflatable Zodiac; birds were either processed in the inflatable boat or delivered to the support vessel for banding. Each bird was fitted with a USGS metal band (size #2), identified to species based on facial plumage, and checked for the presence of bilateral brood patches before release. In 2011 we searched for SCMU in the East Fish Camp vicinity on one night (25 June; 22:00-23:30); no birds were seen or heard. In 2012, we conducted limited capture and banding efforts for SCMU on: (1) 19-20 April at East Fish Camp from 21:10-01:30 hrs; (2) 20 April at Frenchy's Cove from 21:45-23:30 hrs; and (3) 28-29 May at East Fish Camp from 23:07-02:45 hours. The capture effort at Frenchy's Cove was abbreviated due to extremely foggy conditions (approximately 1-2 meter visibility).

**Ashy Storm-Petrel assessment activities.**
We used four techniques to assess ASSP presence and activity: habitat searches, nocturnal mist-netting, ARUs, and observations using night vision goggles. We conducted diurnal habitat assessments for ASSP, CAAU, and SCMU on all three islets using handheld flashlights to search areas with rocky crevice structure that could be accessed without the use of technical climbing equipment. Locations were mapped using handheld GPS units and/or aerial photography maps provided by CINP. Petrel mist-netting was conducted at seven locations over the course of the study; locations were selected to replicate a subset of those used in 1994 efforts, but survey effort in 2011-2012 was much lower than in 1994 (Carter and Whitworth 2013). We lured petrels to mist nets (Avinet: 2.6x9 meters, 4 shelves, 38 mm mesh nets in 2010 and 30 mm mesh nets in 2011) using portable CD players and/or MP3 players. We used decibel meters to standardize, to the extent possible, audio broadcast systems used in this study to broadcast levels used by Carter et al. (1992) to minimize potential bias in capture rates which could result from more powerful technology (e.g. increased broadcast range). Vocalizations for auditory luring were originally

recorded at Southeast Farallon Island (H. Carter pers. comm.). Netting was conducted during dark nights (week of the new moon) in calm conditions (winds less than 15 knots). We used 2.6 x 9 meter nets with four shelves (Avinet, Inc.); in June and July 2011 we used nets with 38 mm mesh but switched to 30 mm nets for the remainder of the study. Each petrel was fitted with a metal USGS band (size 1A); we recorded wing chord, culmen, and tarsus lengths (mm), body weight (using a Pesola scale), and brood patch score as defined in Ainley et al. (1976). We deployed songmeters between April and October (Table 3, Figure 3). Audio data processing results are reported in Chapter 2, below.

**Table 3. Dates and locations of songmeter deployments at Anacapa Island in 2011-2012. Map ID corresponds to locations on Figure 3 map.**

| Map ID | Islet | Deployed | Extracted | Location Description |
|---|---|---|---|---|
| A1 | WAI | 25-May-11 | 6-Jun-11 | Amphitheater shoreline |
| A2 | MAI | 25-May-11 | 27-Jul-11 | Rockfall Cove |
| A3 | WAI | 25-May-11 | 6-Jun-11 | Just east of Pinnacle Cave |
| A4 | WAI | a) 6-Jun-11;<br>b) 5-Mar-12;<br>c) 14-Jul-12 | a) 24-June-11;<br>b) 8-June-12;<br>c) 30-Oct-12 | Portuguese Rock Cove |
| A5 | MAI | 6-Jun-11 | 24-Jun-11 | Just east of Keyhole Cave |
| A6 | WAI | 24-Jun-11 | 26-Jul-11 | Just east of Rat Rock |
| A7 | MAI | 25-Jun-11 | 26-Sep-11 | MAI upper island, South Side |
| A8 | EAI | 26-Jun-11 | 24-Jun-11 | West end of Cathedral Cove |
| A9 | EAI | 26-Jun-11 | 29-Jul-11 | South of water tank on cliff edge |
| A10 | MAI | 26-Jul-11 | 26-Aug-11 | South side just east of Lava#1 |
| A11 | WAI | 25-Aug-11 | 26-Sep-11 | Climb Spine |
| A12 | WAI | 19-Apr-12 | 10-May-12 | West side Frenchy's Cove |
| A13 | WAI | 19-Apr-12 | 29-May-12 | Amphitheatre shoreline |
| A14 | WAI | 19-Apr-12 | 27-May-12 | Big Cliff Beach (West Portion) |
| A15 | MAI | 21-Apr-12 | 29-May-12 | “Hard to Reach Beach” |
| A16 | MAI | 21-Apr-12 | 29-May-12 | East Fish Camp |
| A17 | WAI | 28-May-12 | 16-Jun-12 | Beach East of Frenchy's Beach |
| A18 | MAI | 28-May-12 | 14-Jul-12 | Near Upstairs/Downstairs Cave |
| A19 | WAI | 29-May-12 | 16-Jun-12 | Just West of Moss Cave |
| A20 | WAI | 29-May-12 | 16-Jun-12 | West of Moss Cave |
| A21 | WAI | 18-Jun-12 | 14-Jul-12 | Cat Rock, halfway up backside spine |
| A22 | WAI | 18-Jun-12 | 14-Jul-12 | Rockfall beach east of Cat Rock |
| A23 | WAI | 18-Jun-12 | 14-Jul-12 | East of Lonely at the Top |
| A24 | WAI | 18-Jun-12 | 21-Aug-12 | Below South Bluff |

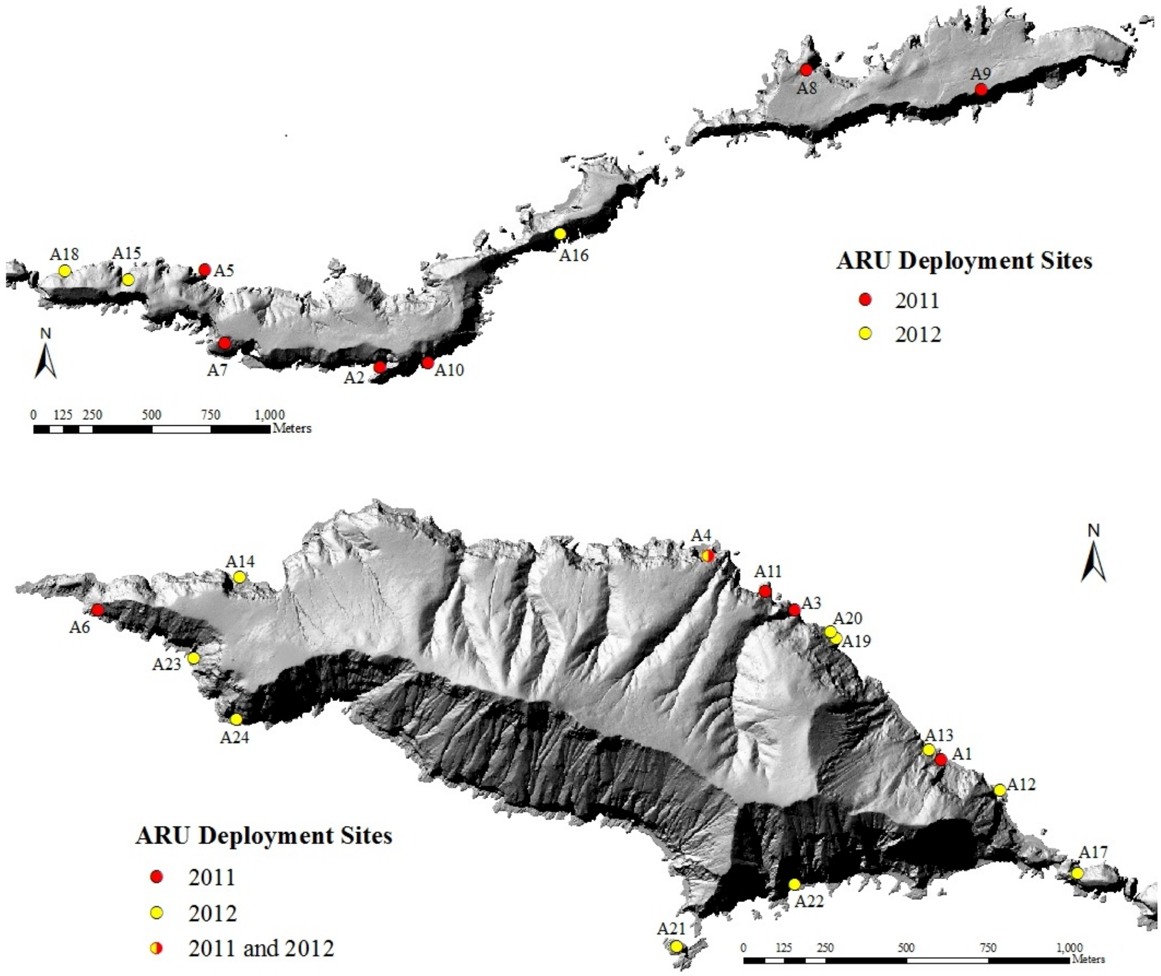


**Figure 3. Songmeter deployment locations at East Anacapa, Middle Anacapa (top panel) and West Anacapa (bottom panel) islets in 2011 and 2012. See text for map number descriptions and recording intervals.**

## RESULTS

### SCMU reproductive monitoring.

In 2011, we monitored a total of 39 clutches, including six sequential clutches, in 33 active sites within the ten regularly monitored plots (Table 4). Overall CS was 72% (n=36 clutches) for all clutches; 73% for first clutches (n=30) and 67% for second clutches (n=6). Sample sizes for all plots were very small (2 to 12 clutches per plot); the lowest CS (40%) in 2011 was from Aerie Cave. Although monitoring intervals were too long to provide fine-scale phenology data (see Whitworth et al. 2009 for discussion), we provide parameters from phenology estimates with initial error rates of less than approximately ±10 days (i.e. survey intervals of less than 20 days).

Using these broad ranges, and resulting lower sample sizes, average clutch initiation from all plots combined occurred on 21 March for first clutches only (n=21 first eggs). The first eggs of the season were laid on 9 March and the latest clutch initiations (from sequential clutches) occurred on 29 May; latest chick departures occurred around 11 July. The breeding season in 2011 therefore spanned an estimated 124 days.

Carcass records were limited to three dead chicks (from 2 clutches, both in Aerie Cave), and 1 adult SCMU carcass (in Moss Cave on 25 May) in 2011. An adult carcass was found at Lonely at the Top on 1 May 2011 adjacent to site 3; the nest subsequently failed. A feather pile was found in Moss Cave on 1 May 2011. Causality for chick deaths is unknown.

**Table 4. Scripps's Murrelet reproductive activity and success from the ten regularly monitored locations in 2011.**

| Plot | Active Sites | Total Clutches | First Clutch Success | *n* |
|---|---|---|---|---|
| Aerie Cave | 4 | 6 | 40% | *5* |
| Keyhole Cave | 0 | 0 | -- | -- |
| Lava Bench #1 | 4 | 4 | 100% | *4* |
| Lava Bench #2 | 2 | 2 | 100% | *2* |
| Lonely at the Top | 2 | 2 | 50% | *2* |
| Moss Cave | 2 | 3 | 100% | *3* |
| Pinnacle Cave | 10 | 12 | 67% | *12* |
| Refuge Cave | 3 | 3 | 100% | *3* |
| Respiring Chimney | 2 | 3 | 67% | *3* |
| Rockfall Cove | 4 | 4 | 50% | *2* |
| **Total** | **33** | **39** | **72%** | ***36*** |

In 2012, we monitored a total of 35 clutches in 33 individual nest sites within the ten regularly monitored plots (Table 5). Overall CS was 83% (n=30 first clutches). Only two sequential clutches were laid in 2012 (one in Pinnacle Cave and one in Refuge Cave), but we could not determine the fate of these late clutches. Island-wide average clutch initiation (which represent success from first clutches only) occurred on 20 March (n=26 clutches). The first eggs of the season were laid on day 48 and the latest clutch initiations (from sequential clutches) occurred on 18 May; latest chick departures occurred near 2 July. The 2012 breeding season therefore spanned an estimated 135 days. We recorded one dead chick (in Refuge Cave) and eight adult SCMU carcasses during the 2012 breeding season as follows: five in Lonely at the Top Cave, one in Aerie Cave, and two in Pinnacle Cave. Based on the presence of wingsets (rather than pellets), as well as frequent observations of Peregrine Falcon (*Falco peregrinus anatum*, PEFA) in these areas, we believe adult mortality may have been caused by PEFA.

**Table 5. Scripps's Murrelet reproductive activity and success from the ten regularly monitored locations in 2012.**

| Plot | Active Sites | Total Clutches | First Clutch Success | *N* |
|---|---|---|---|---|
| Aerie Cave | 2 | 2 | 100% | *2* |
| Keyhole Cave | 0 | 0 | -- | -- |
| Lava Bench #1 | 4 | 4 | 67% | *3* |
| Lava Bench #2 | 3 | 3 | 50% | *2* |
| Lonely at the Top | 3 | 3 | 100% | *3* |
| Moss Cave | 4 | 4 | 100% | *4* |
| Pinnacle Cave | 7 | 8 | 71% | *7* |
| Refuge Cave | 3 | 4 | 33% | *3* |
| Respiring Chimney | 2 | 2 | 100% | *2* |
| Rockfall Cove | 5 | 5 | 100% | *4* |
| **Total** | **33** | **35** | **83%** | ***30*** |

***Comparison to previous data.*** We compared total active nest sites and number of clutches laid in the ten plots chosen for this study (2011-2012) to numbers reported for 2007-2010 from the same ten locations (Whitworth et al. 2008, 2009, 2010). There was a significant linear increase for this short time series ($R^2$=.89; Figure 4). Total clutches also increased through the time series, but at a decreasing rate; the highest clutch per site (CPS) ratio peaked in 2010 (see Harvey et al. 2012 and 2013 for discussion of CPS statistic).

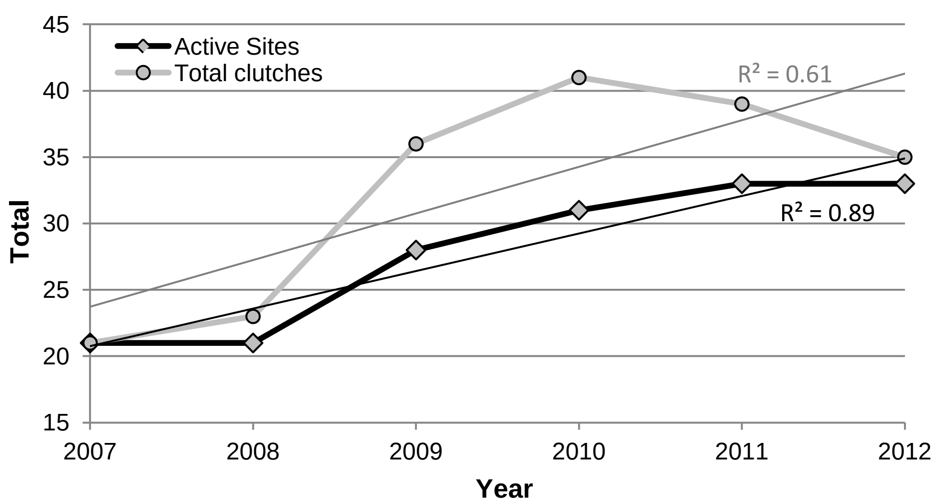


**Figure 4. Total active sites and clutches standardized to the ten locations monitored in the current study. Data for 2007-2010 reproduced from Whitworth et al. (2008, 2009, 2010).**

**SCMU at-sea capture and banding.**
We captured and banded a total of 25 previously unbanded SCMU at Anacapa in 2012 as follows: 19-20 April: 10 unique captures plus one same-night recapture; 20-21 April: 6 unique captures plus one same-night recapture; 28-29 May: 9 unique captures plus one same-night recapture (Figure 5, Appendix 1). Twenty-one percent (21%) of captured birds had brood patches (n=24).

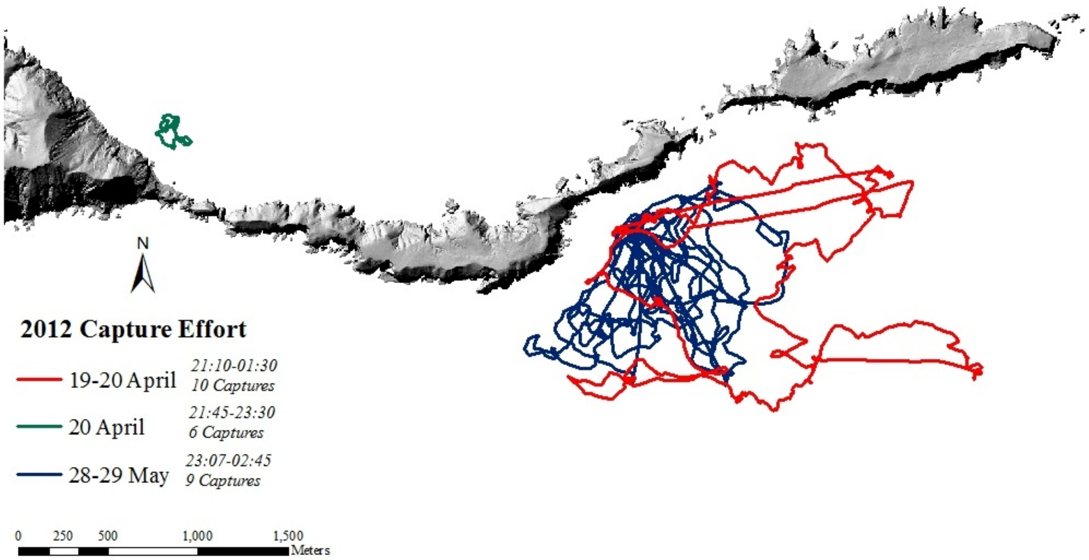


**Figure 5. Scripps's Murrelet at-sea capture and banding effort and results at Anacapa in 2012.**

**ASSP mist-netting.**
In 2011, we captured and banded a total of 20 individual ASSP over seven net-nights (Table 6, Figure 6, Figure 7, Appendix 1). Most (68%, n=19) captured birds had brood patches. Average morphometrics values were: (1) bird weight: 34 g; (2) tarsus length: 24 mm; (3) culmen: 14mm; (4) wing chord: 140 mm, with maximum wing chord of 148 mm (Table 6). In 2012, due to inclement weather during most trips, we attempted to net on only one night (16-17 June); no birds were captured. While we did not capture any petrels on 26-27 July 2011 (Rockfall Cove), using night vision goggles we observed several individuals circling high above the net near the top of the sheer cliffs that define the cove.

**Habitat search areas.** We searched for ASSP, SCMU, and CAAU nesting outside monitored sea caves in accessible shoreline and upper island habitat in each year (Table 7, Figure 8, Appendix 2).

**Table 6. Morphometric data for Ashy Storm-Petrels captured at Anacapa Island in 2011.**

| Measurement | Mean | SD | n |
|---|---|---|---|
| Weight (g) | 34.2 | 2.6 | 20 |
| Tarsus (mm) | 23.8 | 1.1 | 20 |
| Wing Chord (mm) | 140.1 | 3.3 | 20 |
| Culmen (mm) | 13.9 | 0.8 | 20 |

**Figure 6. Ashy Storm-Petrel captured in a mist-net at Rat Rock, West Anacapa Island, on 27 July 2011. Photo D. Mazurkiewicz.**

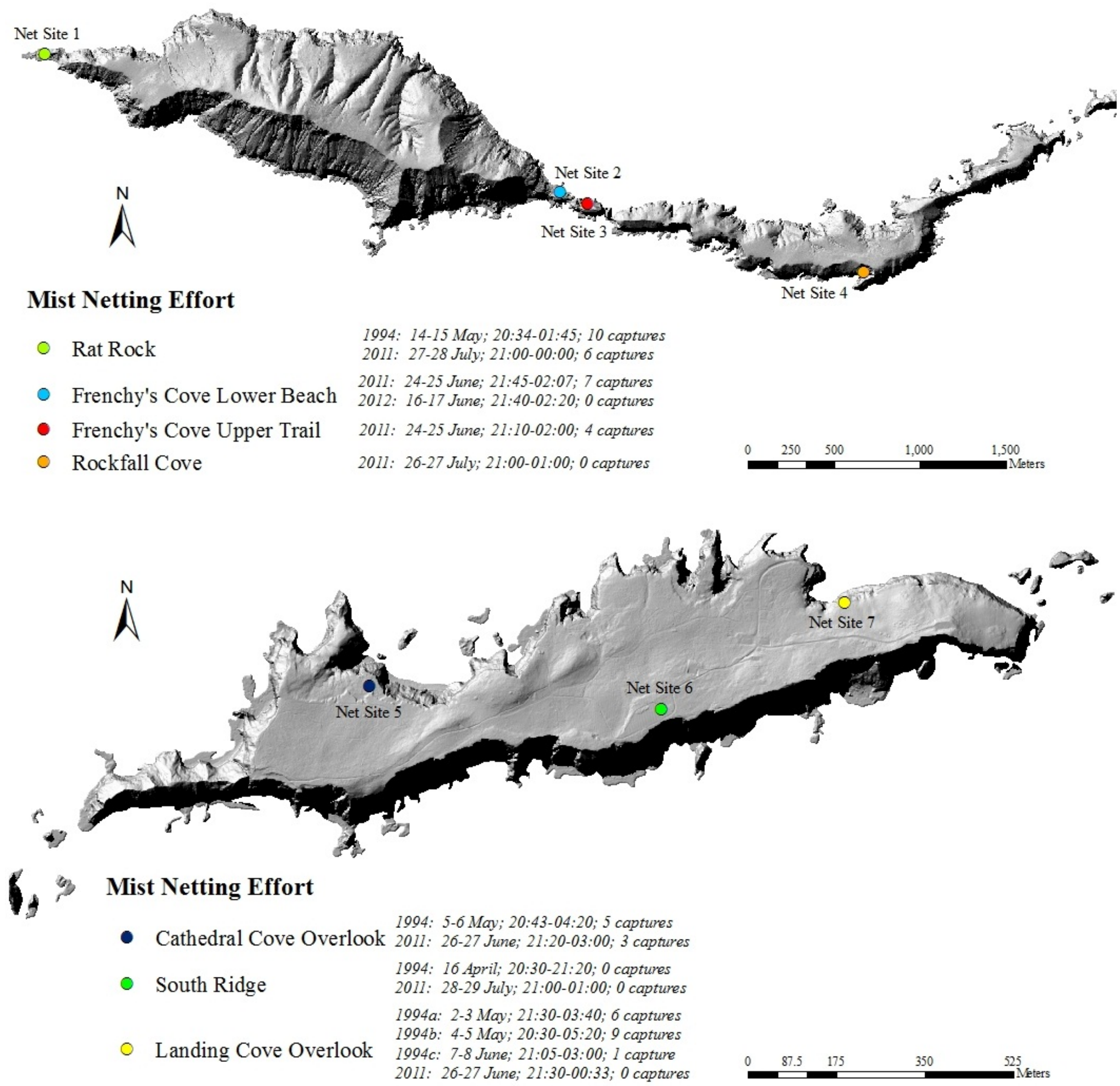


**Figure 7. Ashy Storm-Petrel mist-net effort and total captures in 2011-2012 at WAI and MAI (upper panel) and EAI (lower panel) with 1994 capture data from same net locations for reference. Data from 1994 reproduced from Carter and Whitworth (2013).**

**Table 7. Habitat search locations at Anacapa in 2011 and 2012. See Appendix two for corresponding photographs.**

| Map Identifier | Survey Date | Search Area |
|---|---|---|
| H1 | 24-Jun-11 | Rat Rock |
| H2 | 25-Jun-11 | Upper MAI |
| H2 | 25-Jun-11 | Upper MAI |
| H3 | 26-Jun-11 | Upper EAI |
| H4 | 27-Jun-11 | Sea Cave: The Catacombs |
| H5 | 27-Jun-11 | Sea Cave: Garbage Cove and vicinity |
| H6 | 26-Jul-11 | Shoreline surrounding Lava Bench #1 |
| H7 | 26-Jul-11 | East Fish Camp Cove, West side |
| H8 | 27-Jul-11 | Frenchy's Cove and Amphitheater areas |
| H9 | 29-Jul-11 | Garbage Cove |
| H10 | 25-Aug-11 | Climb Spine |
| H11 | 25-Aug-11 | East and above Lonely at the Top Cave |
| H12 | 26-Aug-11 | Refuge shoreline area (MAI) |
| H13 | 26-Aug-11 | EAI, SE end "Back Door" |
| H14 | 26-Sep-11 | Upper MAI, South side |
| H15 | 27-Sep-11 | Upper WAI |
| H16 | 28-Sep-11 | Upstairs-Downstairs Cave |
| H17 | 28-Sep-11 | Un-named rock |
| H18 | 12-Mar-12 | Tarry Shelves |
| H19 | 23-Mar-12 | East of Lonely at the Top Cave |
| H20 | 23-Mar-12 | Amphitheater |
| H21 | 23-Mar-12 | South Bluff: cave on E. side shoreline |
| H22 | 23-Mar-12 | Hard to Reach Beach (Katy’s Beach) |
| H23 | 23-Mar-12 | Leapyear Cave |
| H24 | 23-Mar-12 | Downview and Uptight caves |
| H26 | 24-Mar-12 | Rat Rock N side |
| H27 | 24-Mar-12 | Rat Rock S side |
| H28 | 24-Mar-12 | No Frills Cave |
| H29 | 24-Mar-12 | Tiny Cave just W of One Shot Cave |
| H30 | 24-Mar-12 | Teardrop Cave |
| H31 | 24-Mar-12 | W. end of Big Cliff beach |
| H32 | 7-Apr-12 | Amphitheater shoreline |
| H33 | 19-Apr-12 | Scree Pile, W. side Frenchy's cove |
| H34 | 21-Apr-12 | Battleship Rock |
| H35 | 29-May-12 | Beach on E. end MAI (s. side) |
| H36 | 14-Jul-12 | WAI South side shoreline |

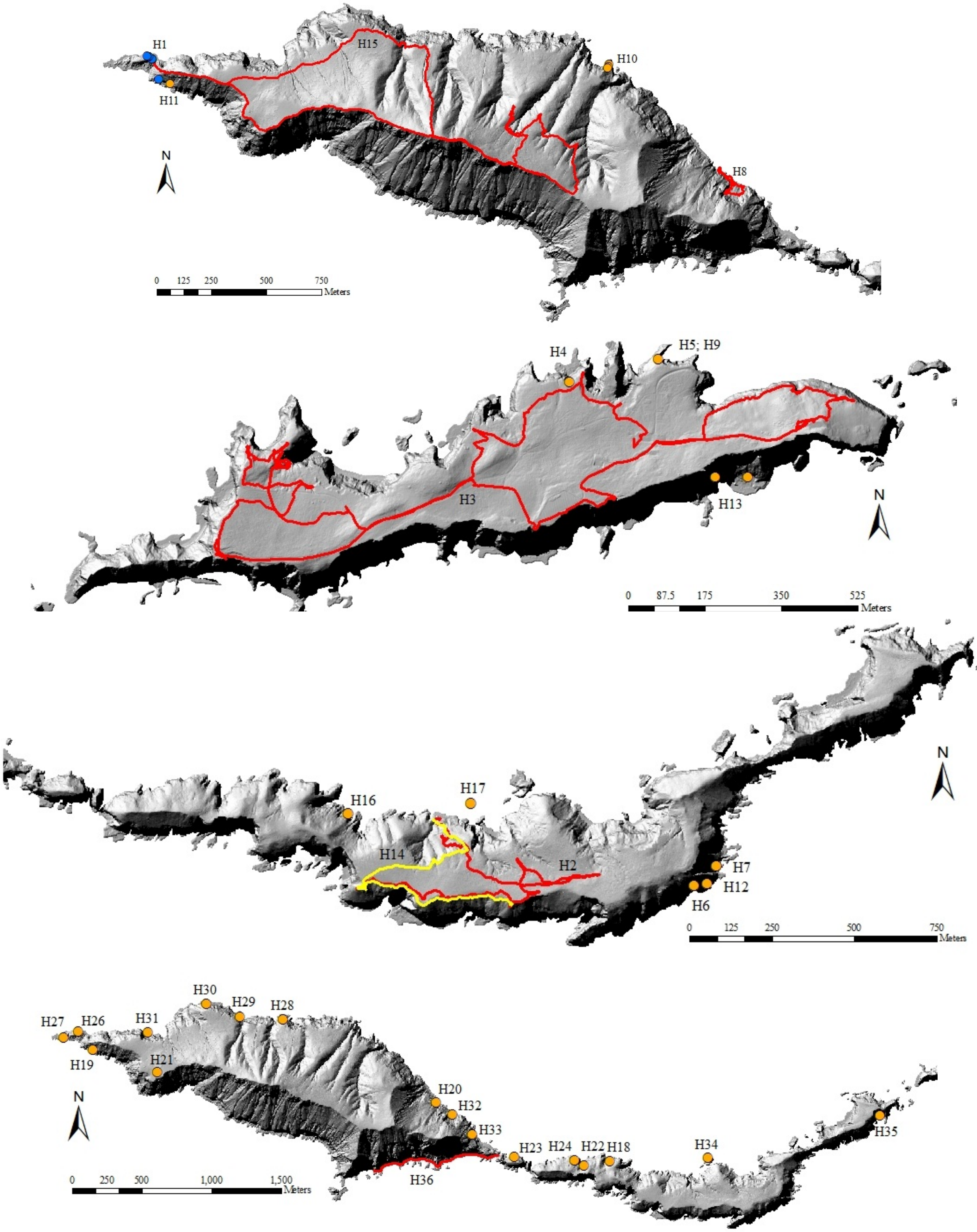


**Figure 8. Habitat search areas outside of standardized monitoring plots in 2011-2012**. From top to bottom, panels show position information for West, East, Middle and a composite of West and Middle islets.

**Ashy Storm-Petrel nesting.**

*Portuguese Rock Cove (Map ID A4, Figure 3, Appendix 2). 2011:* In response to auditory detections from June 22, we searched at Portuguese Rock Cove and discovered one active site (site #1) on 27 August which contained a mostly feathered chick. During a more extensive habitat search on 26 September we found 2 additional ASSP sites containing hatched eggshell fragments. In 2012, site #1 was active, but fledging could not be determined. As an interesting note, we also found what appeared to be an old rat midden in a cave in the upper area of the cove (Figure 9).

**Figure 9. Old rat midden in cave in upper Portuguese Rock Cove. Photo D. Mazurkiewicz.**

**Cassin's Auklets nesting.** We documented active CAAU nesting in three locations and evidence of prior nesting in one additional location as follows.

*Rat Rock (Map ID H26, H27; Figure 8, Appendix 2)*: 24 June 2011: We found 4 active (Site 1: large downy chick; Site 2: adult incubating; Site 3: medium downy chick; Site 4: large gawky chick) plus 13 potential sites (indicated by digging/guano, but unable to confirm if birds present). On 24 March 2012, 3 active sites (Site 1: large downy chick; Site 2: one egg; Site 3: one hatched egg) plus approximately 13 potential sites; only the east end of Rat Rock searched on this date due to large number of roosting cormorants on the west end.

*East Anacapa Islet upper island searches (Map ID#H3, Figure 8, Appendix 2)*. 26 June 2011: Rock wall below lighthouse: 2 active CAAU sites (Site 1: adult plus egg; Site 2: adult in incubating posture). We also noted approximately five additional potential sites in vicinity. 22 August 2012: found 1 CAAU carcass on gravel pad in front of water tank building, EAI.

*East Anacapa Islet, Garbage Cove (Map ID#H5, Figure 8, Appendix 2)*: we visited this location twice in 2011 (27 June and 29 July). The first survey was incomplete; we returned to the cove to explore the abundant potential habitat noted during June. We found one inactive site with old CAAU eggshell.

*Portuguese Rock Cove (Map ID #A4, Figure 3, Appendix 2).* 27 August 2011: 10 to 15 potential CAAU sites. 24 March 2012: 6 to 12 active CAAU sites including at least two sites containing chicks. 21 April 2012: 4 active (Site 1: incubating adult; Site 2: mostly feathered chick; Site 3: incubating adult; Site 4: one freshly depredated egg) plus seven other potential sites, and two CAAU feather piles.

**Scripps's Murrelet nesting.** We documented SCMU nests in eight locations outside of standardized plots as follows.

*North side WAI--Amphitheater shoreline (Map ID#H8, Figure 8, Appendix 2)*: 26 July 2011: one site containing old eggshell fragment, possibly from the previous year. 23 March 2012. 2 SCMU sites (1 incubating adult, 1 inactive site with old eggshell fragments).

*Southeast end EAI "Back Door" (Map ID#H13, Figure 8, Appendix 2)*. 26 August 2011: two SCMU nests (Site 1: 2 hatched eggs; Site 2: 1 depredated egg).

*Portuguese Rock Cov*e *(Map ID #A4, Figure 3, Appendix 2)*. 27 August 2011: two SCMU sites (1 hatched egg each). 21 April 2012: 2 SCMU depredated eggs in open areas but site not found.

*Hard-to-reach beach (Map ID#H22, Figure 8, Appendix 2).* 23 March 2012: one SCMU site (2 hatched eggs), and an additional two to three other potential sites.

*South side Rat Rock (Map ID#H26-27, Figure 8, Appendix 2).* 24 March 2012: one SCMU active site (incubating adult).

*West end of Big Cliff Beach (Map ID#H31, Figure 8, Appendix 2).* 24 March 2012: one SCMU active site (incubating adult) and one SCMU carcass. Also found one ASSP carcass.

*West end Frenchy's cove (Map ID#H33, Figure 8, Appendix 2*. 19 April 2012: one SCMU active site (incubating adult).

*South side WAI beach near Cat Rock (Map ID #22, Figure 3, Appendix 2).* On 18 June 2012. SCMU eggshell fragment found adjacent to ARU placement. On 24 July 2012 at same location found one SCMU active site (incubating adult).

**Other Species: Pigeon Guillemots (PIGU), Black and American Oystercatchers (BLOY, AMOY), Rhinoceros Auklets (RHAU), and Harbor Seals.**

We noted one RHAU in breeding plumage in the water near the South shore of WAI on 27 March 2011 at approximately 09:45. On 20 April 2012, a RHAU in breeding plumage landed on the deck of our support vessel at approximately midnight. A juvenile CAAU also landed on the boat deck that night (approximately 22:40). Weather conditions that night were extremely foggy, with less than 1.5 meter visibility, which also hampered capture efforts (see Methods section). In 2011, we documented four PIGU nests in Keyhole Cave, but no SCMU nesting. On 8 June 2011 (10:00-16:30 hours), we conducted a complete (boat based) round-island survey of the Anacapa islets to census PIGU and BLOY/AMOY numbers. We documented 61 individual oystercatchers (60 BLOY and 1 AMOY) and 12 to 14 nests in the incubation stage. Data were provided to California Audubon Society for their range-wide survey and are reported in Weinstein et al. (*in prep*.). During the same round-island survey, we documented 63 individual PIGU and estimated a minimum of 28 nesting areas. We also documented 86 harbor seals during the survey. We repeated this round-island survey on 28 May 2012; data are archived at CHIS and not reported herein.

## DISCUSSION

***Ashy Storm-Petrel.*** The Ashy Storm-Petrel is a rare procellariiform with an estimated 10,000 breeding individuals worldwide (Ainley 1995, Carter et al. 2008). The breeding distribution is limited primarily to islands along the California and northwestern Baja California coasts; at least half of the breeding population nests on the California Channel Islands. With the exception of Santa Cruz Island, this species has been relatively little studied in the Channel Islands due primarily to the logistical difficulties associated with accessing most nesting areas (i.e. steep cliffs, sea caves, and offshore rocks). At Anacapa Island, breeding was first suspected based on nocturnal mist-net captures of ASSP in April 1994 on the east and west islets (Carter and Whitworth 2013). The presence of ASSP at Anacapa Island in mist-nets in June-August 2002 (during the incubation and chick periods) provided further indication of possible breeding (McIver 2002). In 2000-2003, unidentified storm-petrels also were detected at night using radar surveys at middle islet (Hamer et al. 2005). However, extensive searches for nests of crevice-nesting seabirds in 1994, 1997, and 2000-2010 failed to detect any storm-petrel nests (McChesney et al. 2000; D.L. Whitworth unpubl. data, H.R. Carter unpubl. data).

Because the presence of ASSP in mist nets cannot provide definitive evidence of nesting, we focused our efforts on the combined use of acoustic monitoring and traditional habitat searches on foot during the course of this study. ASSP vocalizations were detected in 2011 from one recording unit deployed from 6 to 24 June at a survey point on the north shore of West Anacapa Island (see Chapter Two). We returned to this location on 27 August for a ground survey and discovered a nest site containing a nearly fledged petrel chick (age≥76 days; see McIver 2002). The nest site was located in shoreline scree habitat in a small cove; we also located several other petrel nest sites there identified by eggshell fragments and characteristic petrel scent. This location had been examined in October 2009 (Whitworth et al. 2011), but no evidence of petrel nesting was found during that survey. We did not find any other nesting locales during searches of sea caves, shorelines, and upper island habitat during 2011, and no other vocalization activity was detected from the 283 hours of recordings sampled from 361 survey nights of audio data processed throughout the season (McKown et al. 2013). However, we captured a small sample (20) of ASSP in mist nets at east and west islets, 68% of which had brood patches, over seven net-nights in June and July 2011.

While there is a remote possibility that the chick was a dark-rumped Leach's Storm-Petrel (*Oceanodroma leucorhoa*) rather than an ASSP chick (these species cannot be differentiated at the chick stage; see Ainley 1995), this is unlikely for the following reasons: (1) Leach's Storm-Petrels have not been observed in mist nets at Anacapa or at Santa Barbara Island in recent years (Harvey et al. 2012, 2013, unpubl. data), (2) of the two species, Ashy Storm-Petrels are much more abundant and widely distributed in the California Channel Islands, and (3) no other petrel species vocalizations were detected from the recording unit data. Based on this evidence, we are confident that the chick found on 27 August 2011 was an ASSP. We have reviewed historical and current literature as well as unpublished reports and data; to our knowledge, this finding represents the first documentation of an active Ashy Storm-Petrel nest site on Anacapa Island.

This study's results may represent either new colonization, recolonization after total colony extirpation caused by introduced predators (particularly Black Rats which were eradicated in 2002; Howald et al. 2005), or recent colony expansion into an area that is possible for researchers to access. While the history of the Anacapa colony will likely never be fully understood, we find that the latter situation is the most likely scenario. Given the high site fidelity of ASSP, as well as the presence of small numbers of ASSP captured in mist-nets in both 1994 and 2011, a remnant breeding population may have persisted at Anacapa Island in inaccessible areas even during the period of Black Rat infestation. Nesting by ASSP in accessible areas (such as the area on WAI where the nest was found in the present study) likely represents an initial expansion of breeding outside of inaccessible areas since rat eradication took place in 2002. Importantly, the cove where we documented the petrel (as well as CAAU and SCMU) nests through the course of this study would have been easily accessible to rats, as evidenced by the presence of an old rat midden in the cove.

***Scripps's Murrelet.*** The SCMU has a limited breeding range, occurring only on the northwestern Baja California islands and the California Channel Islands, with an estimated population of less than 8,000 breeding pairs (Carter et al. 2005, Karnovsky et al. 2005, Whitworth et al. 2013). In California, the Santa Barbara Island colony has long been considered the largest and most important breeding location (Burkett et al. 2003, Carter et al. 2005, 2011). However, the reproductive rates at Anacapa have increased substantially since the eradication of rats in 2001-2002 while in contrast, the SBI population continues to be heavily impacted by at least two native predators (deer mice (*Peromyscus maniculatus elusus*) and Barn Owls (*Tyto alba*);

Burkett et al. 2003, Harvey et al. 2012, 2013). We are unsure of the degree of interaction among Channel Island murrelet colonies. Site fidelity has been reported (Murray et al. 1983); however, these reports are undoubtedly biased by limited sample sizes and site-specific studies. Mark-recapture or other studies to determine rates of emigration and immigration have not been attempted. It seems reasonable to assume that murrelets from the two main Channel Island colonies (SBI and ANI) overlap and mutually contribute to the total reproductive output of this population center.

Whitworth et al. (2013) described the status of the SCMU colony on Anacapa Island during 2001-2010 annual monitoring. We examined a subsample of monitoring locations established in those studies, which indicated that SCMU continued to show improved reproduction. Clutch success (from the 10 sea caves monitored in this study, versus the 13 locations in the Whitworth et al. monitoring program) was 72% in 2011 and 83% in 2012. The density (number of active sites) in sea caves also continued to increase from 2007-2011 and was stable from 2011-2012. We conducted habitat searches to determine whether SCMU were expanding from known colony sites, and recorded 11 SCMU nests outside of the long-term monitoring areas in a total of 9 general locations, indicating that limited colony expansion may be occurring. Whitworth et al. (2010) found six SCMU nests outside of monitored plots during late-season (October) searches in 2009; however, because of the disparity in survey timing and areas, direct comparison is problematic. In the future, overlaying the geographic search area data from the three survey years could provide a more precise comparison, but is beyond the scope of the present study. Nevertheless, it is apparent that a small level of colony expansion has occurred in recent years. We agree with the findings of Whitworth et al. (2013) that sea cave habitat may be nearly saturated, and expect that colony expansion will continue as a result.

***Cassin's Auklet.*** In contrast to the limited population sizes of the ASSP and SCMU, the CAAU breeding bird population was estimated at 3.57 million individuals (Manuwal and Thoresen 1993, Adams 2008). Two subspecies have been recognized: the northern subspecies, *P. a. aleuticus*, occurring from the Bering Sea south through the California Channel Islands, and the southern subspecies, *P.a. australis*, occurring in the Baja California region. Recent genetic analyses, however, indicate that the Channel Island colonies (Prince Island, offshore San Miguel Island, and Scorpion Rock, offshore Santa Cruz Island) are more closely related to the southern subspecies, indicating that gene flow for this species around Point Conception is limited (Wallace et al. in review).

There is little doubt that CAAU colonies on the Channel Islands remain greatly reduced from historic numbers. Howell (1917) stated:

> *"This species probably outnumbers all our other small pelagic birds combined…… They suffer a great deal from the depredations of the Duck Hawks [Peregrine Falcons], a pair or two of which are usually to*

*be found near each colony. The auklets attain an amazing speed when pitching vertically from the tops of the islands upon being released from the hand, but the falcons overtake them with ease, and continue to slaughter after their hunger has been appeased, merely for the fun of it."*

Aside from the species-specific goal of restoring historic colonies of seabirds that have been extirpated by human actions, restoring CAAU to the Channel Islands could also benefit the other species under study by providing increased availability of an avian prey species with larger global population sizes and distributions, which could reduce predation pressure on the rarer ASSP and SCMU. Reestablishing CAAU could also provide an indirect benefit by providing alternative nest habitat for petrels, which may occupy burrows after CAAU chicks fledge from nests. Finally, a bottom-up restoration strategy could ameliorate the effects of the top-down strategy resulting from earlier restoration of avian predators such as Bald Eagles and PEFA on the Channel Islands (MSRP 2005, 2012, Latta 2012, Sharpe 2012). Thus, while the CAAU population size far exceeds that of both SCMU and ASSP, restoration to benefit this burrowing species continues to be an important conservation approach for the Channel Islands system.

***General Monitoring Recommendations for Anacapa.*** While this study focused on collecting reproductive data for just three species, Anacapa Island has great potential to serve as a location at which to collect baseline reproductive data on the majority of seabird species that breed on CINP islands (Table 8). We recommend implementing annual reproductive assessments focusing on multiple species, rather than single-species monitoring. Surveys should be designed to capture the maximum amount of information while accounting for limitations due to cost, effort, potential disturbance, and vagaries of weather. For example, in 2011-2012, approximately 22 days per year of boat-based surveys were sufficient to collect minimum reproductive data for 10 species: Cassin's Auklet, Scripps's Murrelet, Pigeon Guillemot, California Brown Pelican, Brandt's, Double-crested, and Pelagic Cormorants, Black and American Oystercatcher, and Ashy Storm-Petrel. We recommend that this study be used as a model to design an annual basic monitoring plan for these species. Finer scale estimates of reproductive activity (such as that for SCMU) would certainly require a slightly greater effort to allow for shorter survey intervals needed for more precise estimates of productivity and phenology. However, collecting data for multiple species using the same survey platform (support vessel) allows researchers to maximize data collection during relatively costly boat surveys needed to access shoreline and sea cave habitats. For example, conducting basic surveys of California Brown Pelicans opportunistically during the course of this study allowed us to determine that the Anacapa colony continued to decline since the last published report (Burkett et al. 2007); just five young fledged in 2012—the worst reproductive year on record since 1970 (Gress et al. 2003, Burkett et al. 2007).

**Table 8. List of seabird and selected shorebird species that nest on Channel Islands National Park islands. All species listed as breeding on Anacapa Island were documented in both years of the present study (2011-2012). Common names in italics indicate species for which breeding status is presently listed as inactive, extirpated, or not confirmed as breeding.**

| ***Species*** | | ***Breeding Status*** |
|---|---|---|
| **Common Name** | ***Latin name*** | **Anacapa Island** |
| Cassin's Auklet | *Ptychoramphus aleuticus* | Yes |
| Common Murre | *Uria aalge* | No |
| Pigeon Guillemot | *Cepphus columba* | Yes |
| *Rhinoceros Auklet* | *Cerorhinca monocerata* | Unknown; suspected |
| *Tufted Puffin* | *Fratercula cirrhata* | No |
| Scripps's Murrelet | *Synthliboramphus scrippsi* | Yes |
| *Guadalupe Murrelet* | *Synthliboramphus hypoleucus* | No |
| California Brown Pelican | *Pelecanus occidentalis californicus* | Yes |
| Brandt's Cormorant | *Phalacrocorax penicillatus* | Yes |
| Double-crested Cormorant | *Phalacrocorax auritus* | Yes |
| Pelagic Cormorant | *Phalacrocorax pelagicus* | Yes |
| Ashy Storm-Petrel | *Oceanodroma homochroa* | Yes |
| Black Storm-Petrel | *Oceanodroma melania* | Unknown; suspected |
| *Leach's Storm-Petrel* | *Oceanodroma leucorhoa* | Unknown |
| Western Gull | *Larus occidentalis* | Yes |
| Black Oystercatcher | *Haematopus bachmani* | Yes |
| American Oystercatcher | *Haematopus palliatus* | Yes |

**Restoration and conservation recommendations.** One of the primary goals of this study was to determine whether SCMU, CAAU, and/or ASSP could benefit from future restoration efforts on Anacapa Island. Colony attendance patterns and fine-scale (i.e. individual nest site) breeding habitat requirements for the three species share several characteristics. All three species visit breeding sites nocturnally, with peak colony activity occurring typically during dark moon phases, presumably to avoid predation by diurnal avian predators (e.g. Common Raven [*Corvus corax*], PEFA) and to minimize exposure to nocturnal avian predators (e.g. BNOW), respectively (Ainley 1990). CAAU either excavate complex burrows in areas with suitable soil or guano horizons or use existing crevice habitat. ASSP and SCMU do not excavate burrows, instead nesting in a variety of crevice types including rocky fissures, under shrubs or driftwood, and in empty burrows of other seabirds, including CAAU. Burrow or crevice minimum entrance size requirements scale with the body size of the three species.

As a result of our findings of minimal colony expansion by SCMU and CAAU, as well as very small numbers of nesting ASSP, we believe that restoration is warranted. Restoration techniques for each of the three species have been well established during the course of other projects and any future restoration work should use those successful projects as a model. For example, CAAU colony restoration using plant habitat restoration, coupled with artificial habitat and social attraction, has been successfully implemented at both Scorpion Rock offshore SCI (Adams et al. 2009, Adams et al. in prep) and SBI (Harvey et al. 2012, 2013). Ashy Storm-Petrel colony restoration using social attraction and artificial habitat has been effective at SCI, and strategies to protect petrel colonies from native predators are being assessed (McIver et al. 2008, 2009, 2010, 2011, 2013, in prep.). Restoration strategies and recommendations for SCMU throughout their range were summarized by Carter et al. (2011), and efforts to restore shrub habitat and to identify the impacts of predation on the SBI murrelet colony have been described (Harvey and Barnes 2007, Whitworth et al. 2009b, 2011b, Harvey et al. 2012, 2013, Thomsen and Harvey 2012).

Specifically, we recommend the following actions; future restoration work should include a strong monitoring component to assess expected levels of avian predation prior to initiating restoration. Additionally, concurrent studies of ocean conditions and prey availability should be conducted to establish baseline information with which to assess future impacts on nesting seabirds related to climate change.

1. Establish satellite ASSP subcolonies on Anacapa to decrease likelihood of extirpation due to stochasticity. Colony establishment could be accomplished by implementing social attraction (nocturnal vocalization broadcast) in areas with potential natural crevice habitat. This project should be modeled after the successful project on Orizaba Rock, SCI and should consider potential predation issues encountered at SCI that may relate to Anacapa (McIver et al. 2008, 2009, 2010, 2011, 2013, in prep.). Predation by PEFA, CORA and BNOW are of particular concern. Development of a strong monitoring component, including remote monitoring techniques (such as the use of songmeters and remote cameras), would be a key component in order to assess both positive and negative outcomes of restoration. Initial restoration efforts could be focused at one or more of the following locales: Portuguese Rock Cove, Rockfall Cove, Rat Rock, Amphitheater shoreline, Big Cliff Beach, and shoreline scree habitat located on the south side of WAI between Frenchy’s Cove and Cat Rock beach (see Appendix 2).

2. Improve island habitat for CAAU and potentially SCMU by conducting a small native plant restoration effort. Encouraging the expansion of burrow colonies would assist recovery potential for CAAU; ASSP may also benefit by increased availability of structural habitat (ASSP commonly utilize burrows after CAAU fledging has been completed. Establishing native plants may also reduce egg predation by native deer mice by providing an alternative food source, as may be the case on Santa Barbara Island (see Harvey et al. 2012, 2013). While SCMU have not been documented nesting under shrubs on Anacapa, as occurs on SBI and Guadalupe Island (Harvey et al. 2013, D. Whitworth pers. comm..), addition of suitable shrub habitat may encourage colony expansion. Restoration efforts should be focused on Middle and West islets only (East islet is heavily impacted by tourism, lighthouse, and facility use. Native plant restoration efforts should focus on removal of crystalline iceplant (*Mesembryanthemum*

*crystallinum*) and associated annual weeds at the west end of WAI. This population has been expanding since the early 2000s (Harvey pers. obs.), but a small annual effort for three to five concurrent years may be sufficient to eliminate these weedy species from WAI before they spread to an extent that would require a major weed control program.

In addition to the above recommendations, we encourage managers to continue efforts to educate and inform island visitors and researchers about conservation concerns in order to reduce disturbance of the cryptic seabird species nesting on Anacapa Island.

## ACKNOWLEDGEMENTS

We thank the seabird staff and volunteers for enthusiastic field assistance: S. Auer, S. Carr, K. Carter, D. Donnenfield, S. Hall, L. Hennes, M. Jacques, K. Robison, R. Robison, K. White, and A. Yamagiwa. Special thanks to R. Rudolph for assistance with GIS work. H. Carter provided location information for mist-net efforts. Safe transportation to the islands and extensive logistical support was provided by excellent skippers D. Carlson (*Retriever*) and mates E. Berger, T. Shinn; F. Mize (*Fuji III*), and CINP skippers D. Brooks, K. Duran, E. Mayer, and D. Willey (*Ocean Ranger*). Review comments were provided by the Montrose Trustee Council. This project was funded by Montrose Settlements Restoration Program in partnership with Channel Islands National Park and conducted under BBL permit #22539.

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## APPENDICES

**Appendix 1. Band numbers applied at Anacapa for Ashy Storm-Petrels (ASSP) in 2011 and Scripps's Murrelets (SCMU) in 2012.**

| Species | Capture Year | Band Number | Species | Capture Year | Band Number |
|---|---|---|---|---|---|
| SCMU | 2012 | 1262-03446 | SCMU | 2012 | 1262-03508 |
| SCMU | 2012 | 1262-03447 | SCMU | 2012 | 1262-03509 |
| SCMU | 2012 | 1262-03448 | ASSP | 2011 | 4501-41601 |
| SCMU | 2012 | 1262-03449 | ASSP | 2011 | 4501-41602 |
| SCMU | 2012 | 1262-03450 | ASSP | 2011 | 4501-41603 |
| SCMU | 2012 | 1262-03451 | ASSP | 2011 | 4501-41604 |
| SCMU | 2012 | 1262-03452 | ASSP | 2011 | 4501-41605 |
| SCMU | 2012 | 1262-03453 | ASSP | 2011 | 4501-41606 |
| SCMU | 2012 | 1262-03454 | ASSP | 2011 | 4501-41607 |
| SCMU | 2012 | 1262-03455 | ASSP | 2011 | 4501-41701 |
| SCMU | 2012 | 1262-03456 | ASSP | 2011 | 4501-41702 |
| SCMU | 2012 | 1262-03457 | ASSP | 2011 | 4501-41703 |
| SCMU | 2012 | 1262-03458 | ASSP | 2011 | 4501-41704 |
| SCMU | 2012 | 1262-03459 | ASSP | 2011 | 4501-41705 |
| SCMU | 2012 | 1262-03460 | ASSP | 2011 | 4501-41706 |
| SCMU | 2012 | 1262-03461 | ASSP | 2011 | 4501-41707 |
| SCMU | 2012 | 1262-03501 | ASSP | 2011 | 4501-41708 |
| SCMU | 2012 | 1262-03502 | ASSP | 2011 | 4501-41709 |
| SCMU | 2012 | 1262-03504 | ASSP | 2011 | 4501-41710 |
| SCMU | 2012 | 1262-03505 | ASSP | 2011 | 4501-41711 |
| SCMU | 2012 | 1262-03506 | ASSP | 2011 | 4501-41719 |
| SCMU | 2012 | 1262-03507 | ASSP | 2011 | 4501-41787 |

**Appendix 2. Photographs corresponding to habitat search areas, mist net locations, and songmeter placement areas in 2011-2012. Map numbers refer to Figures three, seven, and eight.**

**Figure 1. East Anacapa Island Lighthouse slopes, 26 June 2011, Map ID #H3. Photo by: E. Bergel**

**Figure 2. Songmeter deployment location on WAI Amphitheatre shoreline, Map ID#A1, 25 May 2011. Photo by: L. Harvey**

**Figure 3. Songmeter deployment at Rockfall Cove, Map ID#A2, 25 May 2011.  Photo by: L. Harvey**

**Figure 4. Habitat above songmeter deployment at Rockfall Cove, Map ID#A2, 25 May 2011. Photo by: L. Harvey**

**Figure 5. Songmeter deployment just east of Pinnacle Cave, Map ID#A3, 25 May 2011. Photo by: E. Berger**

**Figure 6. Overview of Portuguese Rock Cove, Map ID#A4, 6 June 2011. Photo by: L. Harvey**

**Figure 7. Songmeter deployment location, Keyhole Cove Point, Map ID#A5, 6 June 2011. Photo by: D. Mazurkiewicz**

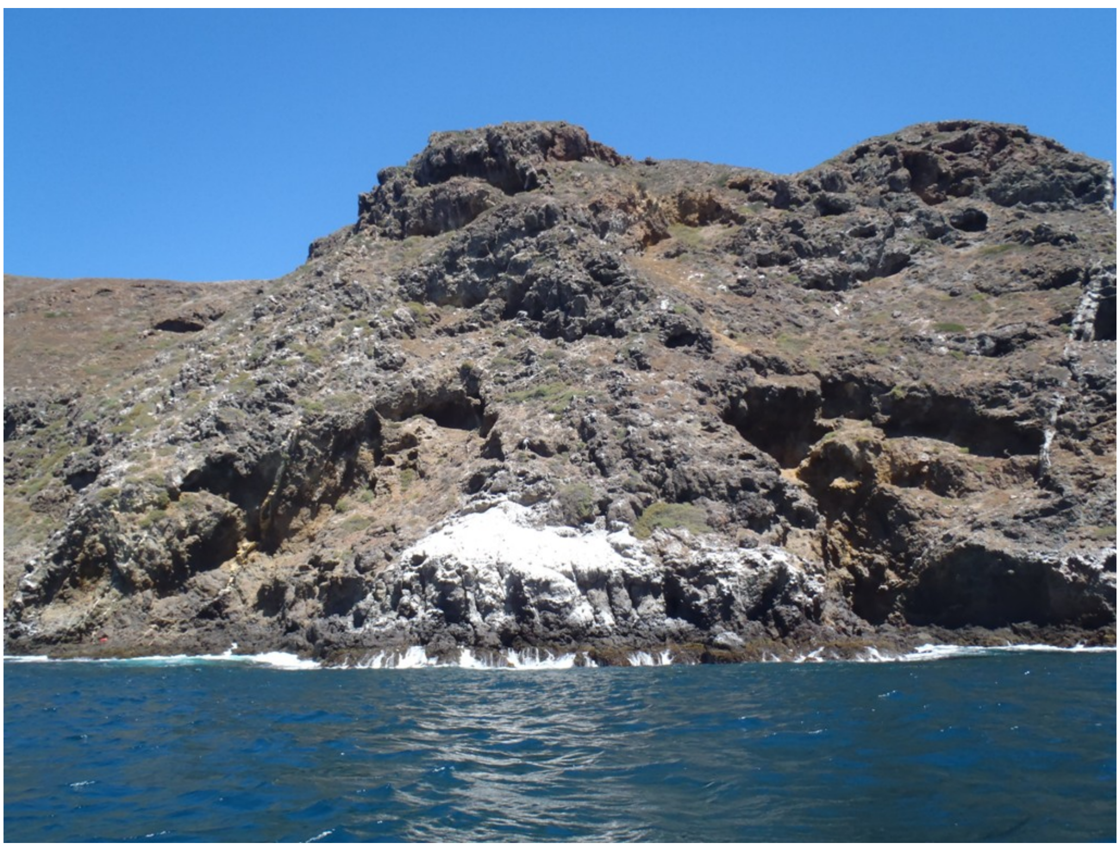

**Figure 8. Songmeter deployment, SW end WAI, Map ID#A6, 24 June 2011. Photo L. Harvey.**

**Figure 9. S. Auer searching MAI South side habitat, Map ID#H2, 25 June 2011. Photo by: L. Harvey**

**Figure 10. MAI South side habitat, Map ID#H2, 25 June 2011. Photo by: L. Harvey**

**Figure 11. Deformed WEGU egg found during MAI habitat searches, 25 June 2011. Photo by: L. Harvey**

**Figure 12. Rat Rock mist-net location,  27 July 2011. Photo by: E. Berger**

**Figure 13. Habitat search, west edge of East Fish Camp, Map ID#H7, 27 July 2011. Photo by: L. Harvey**

**Figure 14. Shoreline habitat, north side WAI, Amphitheater shoreline, Map ID#H8, 27 July 2011. Photo by: D. Mazurkiewicz**

**Figure 15. Upper slope habitat, north side WAI, "Frenchy's Slope," Map ID#H8, 27 July 2011. Photo by: D. Mazurkiewicz**

**Figure 16. EAI South side: "Back Door" overview; two SCMU sites found during habitat search, Map ID#H13, 26 August 2011. Photo by: M. Parker**

**Figure 17. EAI Back Door close-up:  found two SCMU sites during habitat search, Map ID#H13, 26 August 2011. Photo by: M. Parker**

**Figure 18. Entrances to upper cave: Portuguese Rock Cove, 27 August 2011. Photo by: L. Harvey**

**Figure 19. Accessible habitat at the western edge of Portuguese Rock Cove, 27 August 2011. Photo by: L. Harvey**

**Figure 20. Entrance to Garbage Cove, Map ID#H9, 29 July 2011. Photo by: E. Bergel**

**Figure 21. Garbage Cove, Map ID#H9, 29 July 2011. Photo by: D. Mazurkiewicz**

**Figure 22. West Anacapa Island "Climb Spine" habitat overview #1, Map ID#H10, 25 August 2011. Photo by: D. Mazurkiewicz**

**Figure 23. West Anacapa Island "Climb Spine" habitat overview #2, Map ID#H10, 25 August 2011. Photo by: D. Mazurkiewicz**

**Figure 24. Middle Anacapa Island South side habitat overview #1, Map ID#H14, 26 September 2011. Photo by: M. Parker**

**Figure 25. Middle Anacapa Island South side habitat overview #2, Map ID#H14, 26 September 2011. Photo by: M. Parker**

**Figure 26. West Anacapa Island upper island habitat overview #1, Map ID#H15, 27 September 2011. Photo by: M. Parker**

**Figure 27. West Anacapa Island upper island habitat overview #2, Map ID#H15, 27 September 2011. Photo by: M. Parker**

**Figure 28. West Anacapa Island upper island habitat overview #3, Map ID#H15, 27 September 2011. Photo by: M. Parker**

**Figure 29. Tarry Shelves habitat search location, Map ID#H18, 12 March 2012. Photo by: L. Harvey**

**Figure 30. Habitat search area to east of Lonely at the Top Cave, Map ID#H19, 23 March 2012. Photo by: L. Harvey**

**Figure 31. Shoreline scree and unnamed small cave on southeast side WAI, Map ID#H21, 23 March 2012. Photo by: L. Harvey**

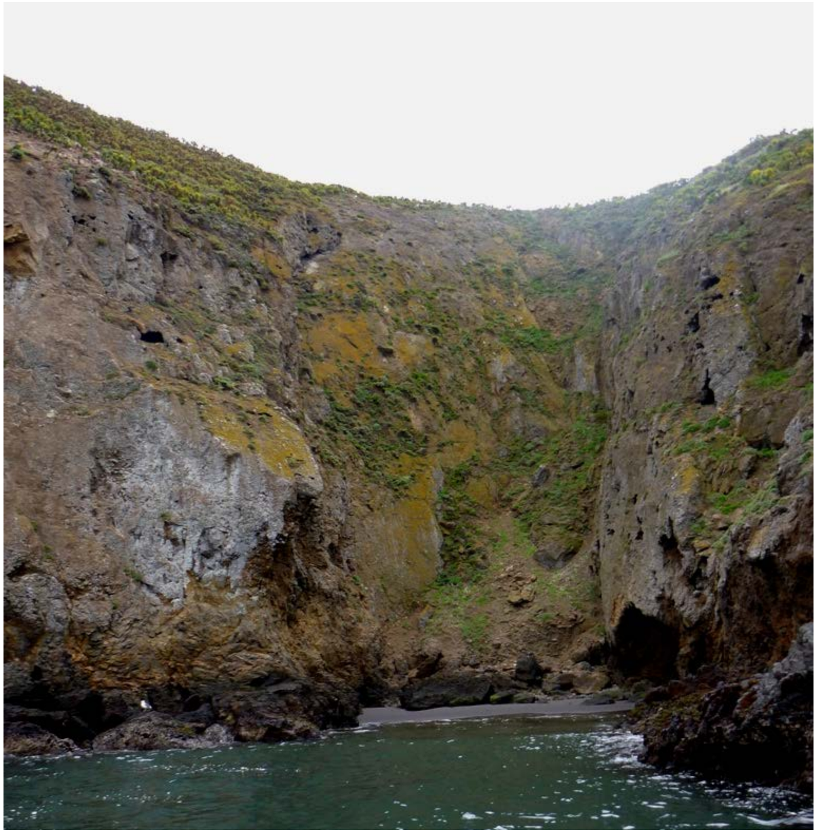

**Figure 32. Hard to Reach Beach, Map ID#H22, 23 March 2012. Photo by: L. Harvey**

**Figure 33. Downview and Uptight Caves, Map ID#H24, 23 March 2012. Photo by: L. Harvey**

**Figure 34. Habitat above Downview and Uptight Caves, Map ID#H24, 23 March 2012. Photo by: L. Harvey**

**Figure 35. Leap Year Cave, Map ID#H23, 23 March 2012. Photo by: L. Harvey**

**Figure 36. No Frills Cave, Map ID#H28, 24 March 2012. Photo by: L. Harvey**

**Figure 37. Unnamed small cave just west of One Shot Cave, Map ID#H29, 24 March 2012. Photo by: L. Harvey**

**Figure 38. Teardrop Cave, Map ID#H30, 24 March 2012. Photo by: L. Harvey**

**Figure 39. Big Cliff Beach and surrounding cliffs. Possible PEFA aerie also noted on cliffs above beach, Map ID#H31, 24 March 2012. Photo by: L. Harvey**

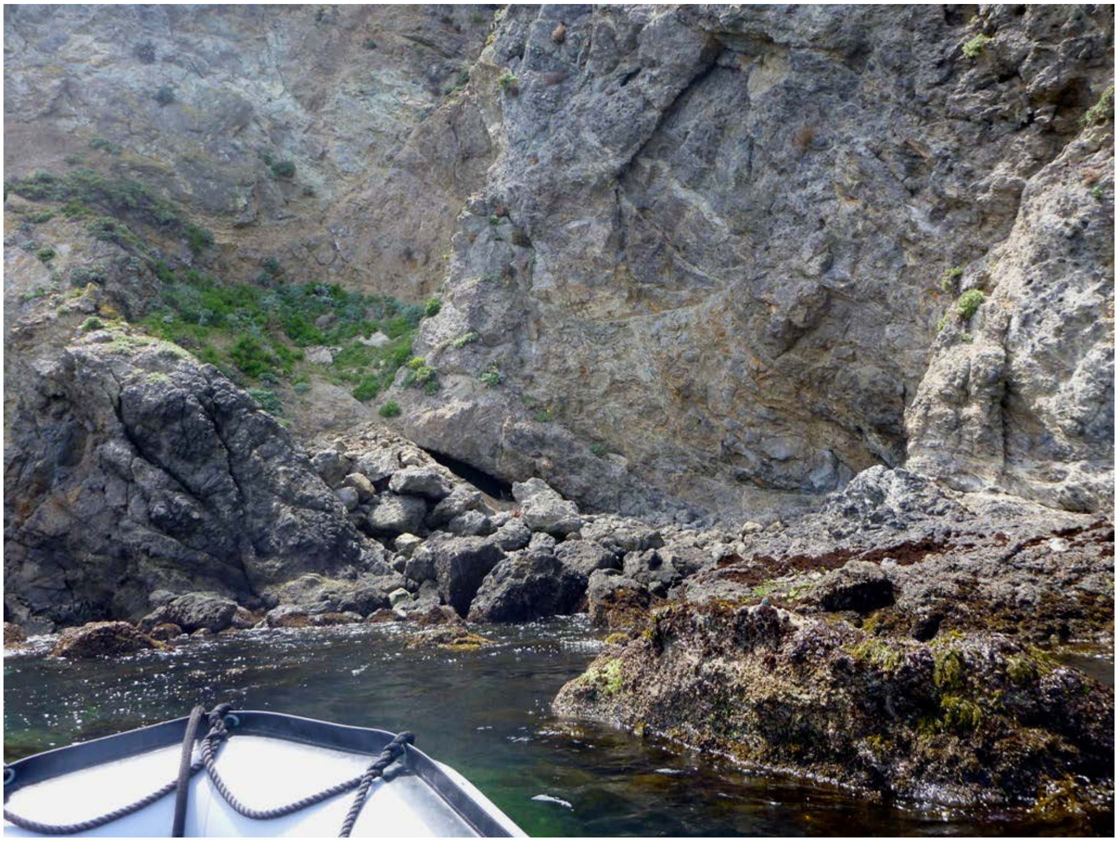

**Figure 40. Shoreline scree habitat, west side of Frenchy's Cove, Map ID#H33, 19 April 2012. Photo by: L. Harvey**

**Figure 41. East Fish Camp cobble habitat, 21 April 2012. Photo by: L. Harvey**

**Figure 42. Songmeter placement east of Frenchy's Beach, Map ID#A17, 28 May 2012. Photo by: A. Yamagiwa**

**Figure 43. Songmeter placement west of Moss Cave, Map ID#A19, 29 May 2012. Photo by: A. Yamagiwa**

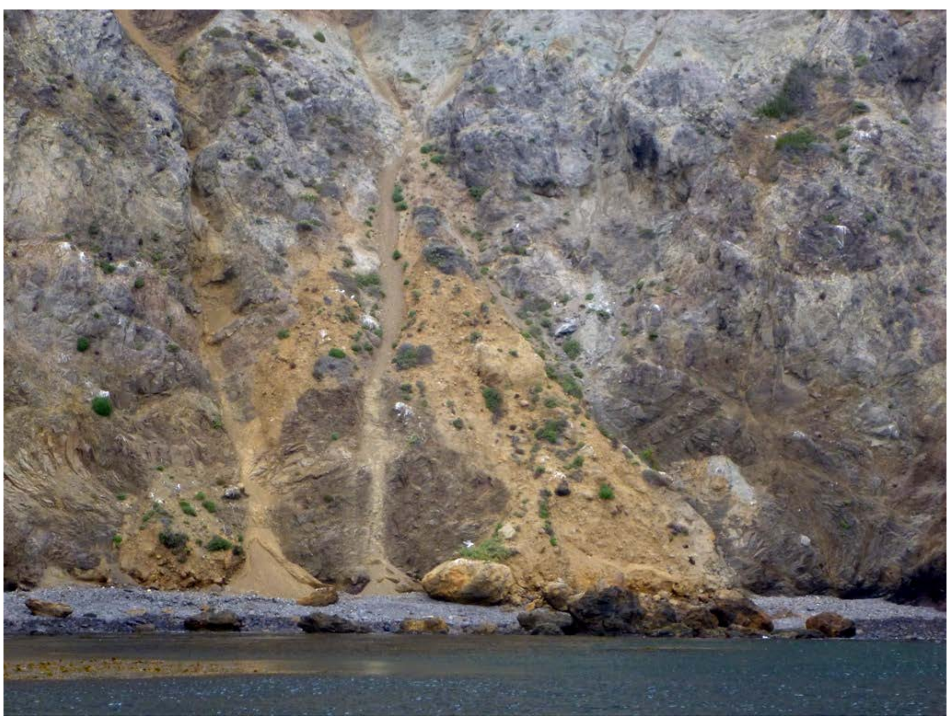

**Figure 44. Beach on South side of WAI (ARU and habitat search); SCMU eggshell fragment found here; Map ID#A22, 18 June 2012. Photo by: L. Harvey**

**Figure 45. Songmeter deployment location, east of Lonely at the Top cave, Map ID#A23, 18 June 2012. Photo by: L. Harvey**

**Figure 46. Southwest corner of WAI, Map ID#A24, 18 June 2012. Photo by: L. Harvey**

**Figure 47. Shoreline habitat, south side West Anacapa Island, Map ID#H36, 14 July 2012. Photo by: L. Harvey**

**Figure 48. The southwestern aspect of West Anacapa Island. Photo by: M. Parker**

# Chapter Two

# Passive acoustic surveys for Ashy Storm-Petrel vocal activity (*Oceanodroma homochroa*) on Anacapa Island in 2011 and 2012

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## Executive Summary

Comprehensive surveys of seabird breeding activity were carried out on Anacapa Island in 2011 and 2012, ten years after the eradication of invasive rats (Harvey et al. 2013). Part of the Montrose Settlements Restoration Program (MSRP 2005), this report summarizes the results from a novel survey method employed by the project - passive acoustic surveys with automated sensors. The technique provided a number of advantages for detecting one of the primary survey targets – the Ashy Storm-Petrel (*Oceanodroma homochroa*), a rare and elusive species that nests in rock crevices and only returns to breeding sites at night.

Ashy Storm-Petrel vocalizations were detected at one survey location - Portuguese Rock on West Anacapa Island – in both survey years. Visual surveys at this site in 2011 documented the first confirmed breeding site for Ashy Storm-Petrel on Anacapa Island.

## Introduction/Background

In 2011, the Montrose Settlements Restoration Program funded a two-year collaborative survey effort to determine the status of Ashy Storm-Petrels (*Oceanodroma homochroa*) and other seabirds on Anacapa Island (CA). Previous seabird monitoring efforts had documented the recovery of Scripps's Murrelet (*Synthliboramphus scrippsi*) on the island following the successful eradication of Black Rats (*Rattus ratus*) in 2002 (Whitworth et al. 2012). Ashy Storm-Petrel breeding sites had not been documented on Anacapa Island, but active colonies on adjacent Santa Cruz Island suggested that without rats, Anacapa Island would be suitable breeding habitat for this California bird Species of Special Concern (Carter et al. 2008).

The project's survey design combined a variety of land-based survey techniques as well this novel approach – passive acoustic surveys, a new technology that can increase the probability of detecting rare and elusive species like the Ashy Storm-Petrel. Automated acoustic sensors greatly enhance wildlife surveys by providing nearly continuous sampling effort at remote locations where it is otherwise impractical, cost-prohibitive, dangerous, or destructive to survey the habitat with field crews.

This report details the results of the 2011 and 2012 passive acoustic surveys from Anacapa Island.

### Automated acoustic sensors for ecological monitoring

Acoustic cues have long been an important part of bird monitoring projects (Sauer et al. 1994). Recent technological innovations now make it possible to deploy weatherproof acoustic sensors that can reliably sample for many months. The resulting hundreds of hours of field recordings are then processed with pattern recognition software to automatically derive measures of acoustic activity rates by species of interest. Passive acoustic sensors and automated call detections are thus tools that can facilitate monitoring programs for rare/elusive species in remote locations (Acevedo & Villanueva-Rivera 2006; Agranat 2007; Brandes 2008a; Brandes 2008b).

To date, passive acoustic sensors have been deployed to search for rare bird species (e.g. Ivory-billed Woodpeckers (*Campephilus principalis*; Swiston & Mennill 2009), to monitor the presence and abundance of secretive land mammals (e.g. rainforest elephants, *Loxodonta cyclotis*; Thompson et al. 2010), and to document the movement of songbirds and bats during migration (Farnsworth et al. 2004; Farnsworth & Russell 2007; Kunz et al. 2007).

Acoustic sensors are also an effective tool for monitoring seabirds (Buxton & Jones 2012; McKown 2008). Since 2010, we conducted acoustic monitoring of 22 seabird species in 8 families with the U.S. Fish and Wildlife Service, National Park Service, state wildlife agencies and conservation organizations, including Island Conservation. These projects include several species of conservation interest including — Hawaiian Petrel (*Pterodroma sandwichensis*), Newell's Shearwater (*Puffinus newelli*), Band-rumped Storm-Petrel (*Oceanodroma castro*), Ashy Storm-Petrel, Leach's Storm-Petrel (*O. leucorhoa*), Tristram's Storm-Petrel (*O. tristrami*), and Marbled Murrelet (*Brachyramphus marmoratus*).

## Methods

### Acoustic Sensors

Six passive acoustic sensors (Song Meter 2's from Wildlife Acoustics, Inc.; http://www.wildlifeacoustics.com) were deployed at 11 coastal surveys sites on Anacapa Island from May to September 2011 and at 14 sites from March to September 2012. Song Meters are single-board computers housed in a weatherproof box and powered by four internal D-cell alkaline batteries. For this project, sensors were deployed with one 32-GB SD memory card to store all field recordings. Each sensor was fitted with a single SMX-II omni-direction microphone (Wildlife Acoustics, Inc.) and set to record on the left channel at a sampling rate of 22 kHz (16 bits). Recordings were stored as uncompressed ".wav" files. Sensors were placed on the ground at survey sites with the omni-directional microphones oriented vertically (upwards). Rocks or stakes were used to hold the sensor in place. Sensors are only designed to record ambient acoustic activity and did not emit sounds.

### Recording Schedule

A recording schedule was programmed using the SMCONFIG software (Version 2.2.4 Wildlife Acoustics, Inc.). Each sensor was programmed to record for one minute out of every ten minutes (i.e. six recordings per hour) on each night, from local sunset to local sunrise, when Ashy Storm-Petrel are active at breeding sites. This recording schedule provided a sample of activity patterns at survey sites while maximizing battery life. Sensors deployed with this program had approximately three months of battery life per deployment.

Sensors were deployed by field staff conducting traditional visual surveys at sites across all three sections of Anacapa Island (East, Middle, and West). After each survey period, recordings were copied from the sensors and sent to Conservation Metrics for analysis.

**Sampling area**

The distance at which a sound can be recorded by the Song Meter-2 microphone is dependent on a number of factors including the amplitude and spectral properties of the sound, distance and elevation of sound source, the amplitude of biotic and abiotic background noises (primarily other animals, wind and surf) and physical features of the survey site (Brenowitz 1982, Wiley & Richards 1978). These same features also influence the sensitivity and accuracy of the automated classification techniques, as well as human auditory surveys.

Through a series of audio playbacks at a coastal site in Santa Cruz, CA, we estimate that sensors are consistently detecting seabird vocalizations (played at 65dB 1m from the speaker) broadcast from within a ~55 m radius of the sensor. Louder sounds could be detected at greater distances (100m), but only during still and quite periods.

**Automated call detection**

Automated analysis of field recordings was carried out with the eXtensible BioAcoustic Tool (XBAT, http://www.xbat.org), a bioacoustic analysis software package that includes algorithms for detecting sounds of interest on acoustic recordings. Specifically, we used a visual pattern recognition technique known as spectrogram cross-correlation to detect sounds correlated with the spectral qualities of Ashy Storm-Petrel vocalizations (Mellinger & Clark 2000). The technique compared sounds from field recordings to previously recorded examples of Ashy Storm-Petrel aerial vocalizations (our search templates). The search template we used for the Anacapa Island project consisted of 5 exemplars of Ashy Storm-Petrel aerial calls from breeding sites on Southeast Farallon Island. We chose to search for aerial calls, as these are used for long-distance communication, and are common within 55m of breeding sites at known breeding sites on Southeast Farallon.

The same search template was used in both years and detected 75% of the known calls on a control dataset including a known number of Ashy Storm-Petrel aerial calls.

We manually reviewed all of the events detected by the software program and removed all sounds that had been misidentified as Ashy Storm-Petrel vocalizations. We also inspected a random sample of 10% of the recordings from all survey locations to search for any Ashy Storm-Petrel vocalizations missed by XBAT.

**Statistical Analysis**

Traditional surveys undertaken by field teams are usually limited to a few days or hours of survey effort per site, thereby reducing the probability of detecting rare and illusive species. In addition, these sporadic survey efforts can severely limit the statistical power of monitoring programs to detect changes in population size over time (Fuller and Dhanjal-Adams 2012). In contrast, the nearly continuous monitoring data provided by automated acoustic sensors facilitates the detection of rare and elusive species like the Ashy Storm-Petrel and greatly increases the statistical power to detect changes in population size.

For this study, the acoustic metrics of interest at each site were: a) presence/absence of Ashy Storm-Petrel acoustic activity, and b) mean acoustic activity rates over the sampling period (mean calls per minute (+/- SD)).

## Acoustic Results

**Survey Effort**

Acoustic sensors were deployed at a total of 24 survey sites on East, Middle, and West Anacapa - 11 survey points from May 25 to September 26, 2011, and 14 sites from March 5 to October 30, 2012 (Figure 2-1, Table 2-1 and Table 2-2). One point, A4, was surveyed in both years. In addition, an active Ashy Storm-Petrel colony was surveyed at Scorpion Rock (off of Santa Cruz Island) in 2011.

A total of 710 hours of recordings were collected over a combined total of 897 survey nights in 2011 and 2012 (2011= 283 hours of recordings on 361 survey nights; 2012= 427 hours of recordings on 536 survey nights). Only 2 sensor deployments failed to record during the survey period – one microphone failure in 2012, and an unknown problem in 2011.

**Ashy Storm-petrel acoustic Activity**

Ashy Storm-Petrel vocal activity was only detected at the A4 (Portuguese Rock) survey site on West Anacapa Island in 2011 and 2012 (*Figure* 2-2; Table 2-3 and Table 2-4). Mean Ashy Storm-Petrel acoustic activity rates were 0.09 (+/- 0.14 S.D.) calls per minute during the 19 survey nights in 2011 and 0.06 calls per minute (+/- 0.17 S.D.) during the 106-night survey period in 2012. By comparison, 2011 activity rates at a known Ashy Storm-Petrel colony at Scorpion Rock (off the nearby Santa Cruz Island) were roughly twice that measured at the A4 site (Table 2-3).

At survey site A4, Ashy Storm-Petrel calls were detected on 10 of 19 survey nights (53%) and 29 of 106 survey nights (27%) in 2011 and 2012, respectively. Ashy Storm-Petrel acoustic activity was detected between 21:00 and 04:59, with peak activity measured between 01:00 and 03:59 (*Figure 2-4*).

The earliest Ashy Storm-Petrel call of the 2012 survey period was detected on March 29 and the last call was detected July 22, just before the microphone failed on the A4 Song Meter (*Figure* 2-5).

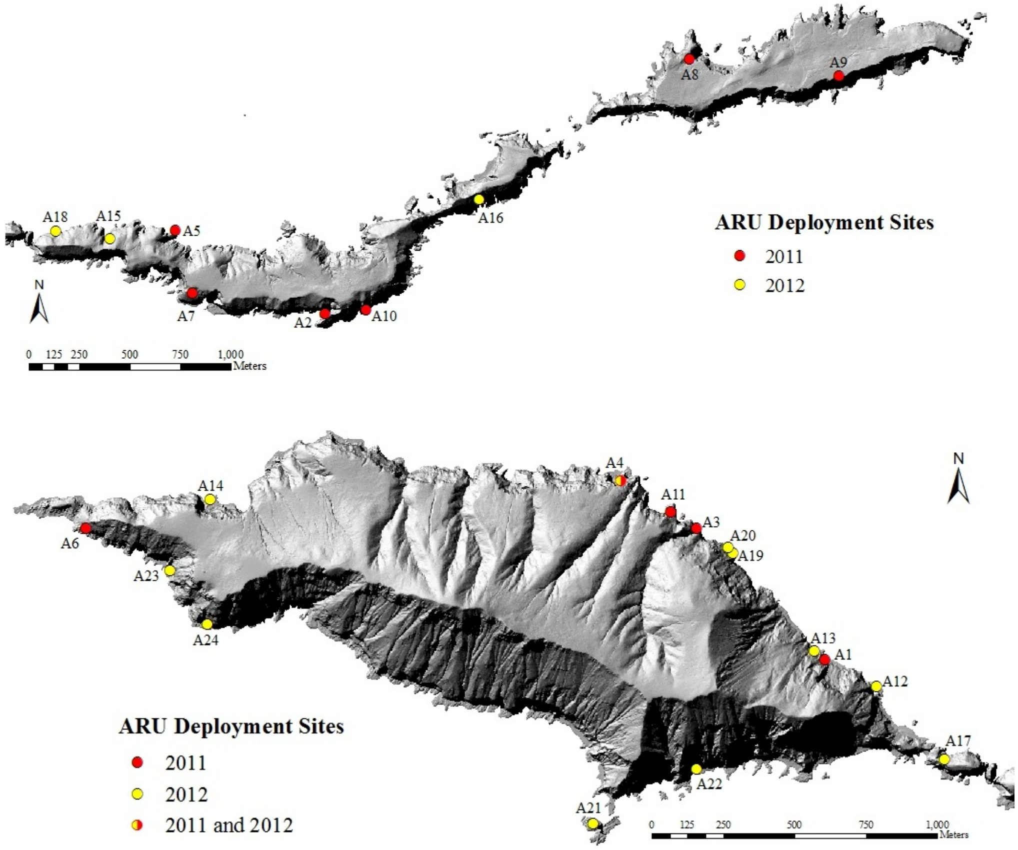


***Figure 2-1 Songmeter deployment locations at East Anacapa, Middle Anacapa (top panel) and West Anacapa (bottom panel) islets in 2011 and 2012. See text for map number descriptions and recording intervals.***

***Table 2-1*** **Acoustic survey effort Anacapa Island – 2011**

| ***Survey Point*** | ***Location*** | ***Lat.*** | ***Long.**** | ***Deployed*** | ***Retrieved*** |
|---|---|---|---|---|---|
| **A1** | W. AI | 277060 | 3765845 | 5/25/11 | 6/6/11 |
| **A2** | M. AI | 279108 | 3765074 | 5/25/11 | 7/27/11 |
| **A3** | W. AI | 276611 | 3766303 | 5/25/11 | 6/6/11 |
| **A4** | W. AI | 276347 | 3766469 | 6/6/11 | 6/24/11 |
| **A5** | M. AI | 278369 | 3765487 | 6/6/11 | 6/24/11 |
| **A6** | M. AI | 278452 | 3765177 | 6/25/11 | 9/26/11 |
| **A7 (1)** | W. AI | 274479 | 3766301 | 6/24/11 | 7/26/11 |
| **A7 (2)** | W. AI | 274479 | 3766301 | 8/27/11 | 9/26/11 |
| **A8** | E. AI | 280919 | 3766338 | 6/26/11 | 7/29/11 |
| **A9** | E. AI | 281662 | 3766252 | 6/26/11 | 7/29/11 |
| **A10** | M. AI | 279316 | 3765094 | 7/26/11 | 8/26/11 |
| **A11** | W. AI | 276520 | 3766357 | 8/25/11 | 9/26/11 |
| **SR1** | Sc. Rock | 264857 | 3770346 | 6/26/11 | 7/14/11 |

* GPS Map Projection = NAD83

***Table 2-2*** **Acoustic survey effort Anacapa Island - 2012**

| *Survey Point* | *Location* | *Lat.** | *Long.** | *Deployed* | *Retrieved* |
|---|---|---|---|---|---|
| **A4** | W. AI | 276356 | 3766475 | 3/5/12 | 6/8/12 |
| **A12** | W.AI | 277239 | 3765750 | 4/19/12 | 5/10/12 |
| **A13** | W.AI | 277023 | 3765873 | 4/19/12 | 5/29/12 |
| **A14** | W.AI | 274913 | 3766402 | 4/19/12 | 5/27/12 |
| **A15** | M. AI | 278119 | 3765502 | 4/21/12 | 5/29/12 |
| **A16** | M. AI | 279700 | 3765511 | 4/21/12 | 5/29/12 |
| **A17** | W.AI | 277477 | 3765497 | 5/28/12 | 6/16/12 |
| **A18** | M. AI | 277771 | 3765485 | 5/28/12 | 7/14/12 |
| **A19** | W.AI | 276738 | 3766215 | 5/29/12 | 6/16/12 |
| **A20** | W.AI | 276721 | 3766233 | 5/29/12 | 6/16/12 |
| **A21** | W.AI | 276261 | 3765246 | 6/18/12 | 7/14/12 |
| **A22** | W.AI | 276605 | 3765253 | 6/18/12 | 7/14/12 |
| **A23** | W.AI | 274771 | 3766154 | 6/18/12 | 7/14/12 |
| **A24** | W. AI | 274903 | 3765968 | 6/18/12 | 8/21/12 |

*GPS Map Projection = NAD83; Zone 11N

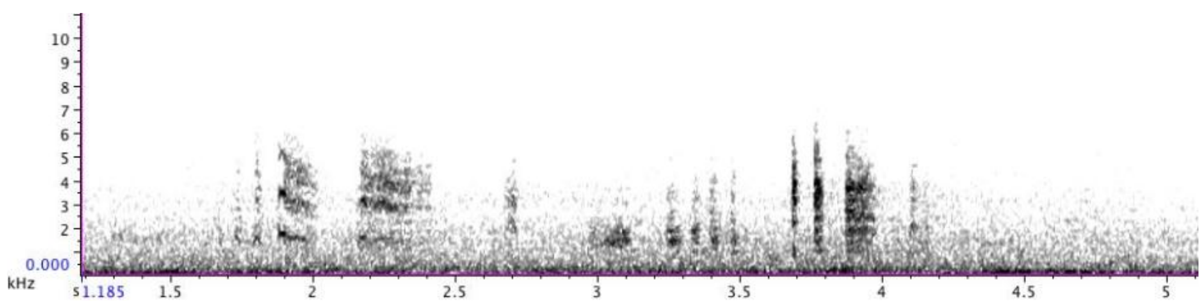


***Figure 2-3*** ***Spectrogram of first Ashy Storm-Petrel aerial vocalizations detected at survey point A4 at Portuguese Rock on West Anacapa Island (June 22, 2011 - 03:47)***

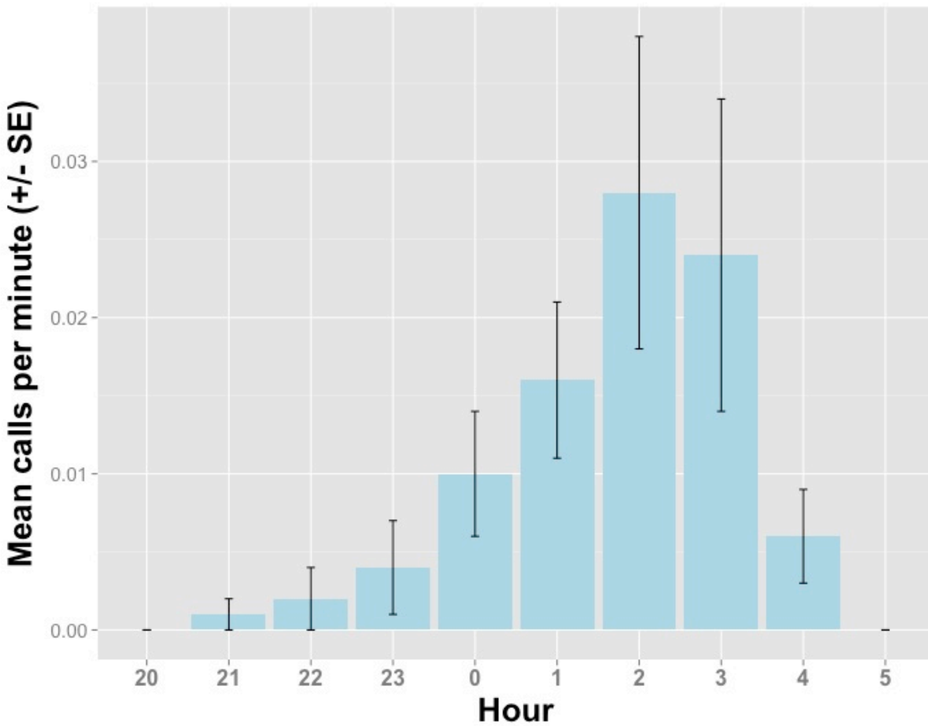


***Figure 2-4 Mean Ashy Storm-Petrel acoustic activity by hour of night at survey site A-4 (2012)***

***Table 2-3*** **Ashy Storm-Petrel acoustic activity at survey sites - 2011**

| *Survey Point* | *Survey Nights* | *Survey Hours* | *Nights Present* | *Percent of survey nights* | *Mean Calls/min (+/- sd)* |
|---|---|---|---|---|---|
| A1 | 13 | 9 | 0 | 0 | 0.00 (0.00) |
| A2 | 64 | 48 | 0 | 0 | 0.00 (0.00) |
| A3 | 13 | 9 | 0 | 0 | 0.00 (0.00) |
| A4 | 19 | 14 | 10 | 53% | 0.09 (0.14) |
| A5 | 19 | 14 | 0 | 0 | 0.00 (0.00) |
| A6 | 45 | 35 | 0 | 0 | 0.00 (0.00) |
| A7 | 64 | 54 | 0 | 0 | 0.00 (0.00) |
| A8 | 34 | 26 | 0 | 0 | 0.00 (0.00) |
| A9 | 34 | 26 | 0 | 0 | 0.00 (0.00) |
| A10 | 4 | 3 | 0 | 0 | 0.00 (0.00) |
| A11 | 33 | 31 | 0 | 0 | 0.00 (0.00) |
| SR1 | 19 | 14 | 16 | 84% | 0.20 (0.19) |

*Table 2-4* **Ashy Storm-Petrel acoustic activity at survey sites - 2012**

| ***Survey Point*** | ***Survey Nights*** | ***Survey Hours*** | ***Nights Present*** | ***Percent of survey nights*** | ***Mean Calls/min (+/- s.d.)*** |
|---|---|---|---|---|---|
| A4 | 106 | 92 | 29 | 27% | 0.06 (+/- 0.17) |
| A12 | 22 | 18 | 0 | 0 | 0.00 (0.00) |
| A13 | 40 | 33 | 0 | 0 | 0.00 (0.00) |
| A14 | 39 | 32 | 0 | 0 | 0.00 (0.00) |
| A15 | 38 | 31 | 0 | 0 | 0.00 (0.00) |
| A16 | 39 | 32 | 0 | 0 | 0.00 (0.00) |
| A17 | 20 | 14 | 0 | 0 | 0.00 (0.00) |
| A18 | 48 | 36 | 0 | 0 | 0.00 (0.00) |
| A19 | 19 | 14 | 0 | 0 | 0.00 (0.00) |
| A20 | 19 | 14 | 0 | 0 | 0.00 (0.00) |
| A21 | 27 | 20 | 0 | 0 | 0.00 (0.00) |
| A22 | 27 | 20 | 0 | 0 | 0.00 (0.00) |
| A23 | 27 | 20 | 0 | 0 | 0.00 (0.00) |
| A24 | 65 | 51 | 0 | 0 | 0.00 (0.00) |

*Sensitivity of automated detection template*

A total of 8,016 sounds were flagged as potential ASSP calls during the automated detection process. We audited all detections and determined that 97% of these were misclassified sounds. The high rate of false alarms was a direct result of our choice to use a highly sensitive detection template. We manually reviewed all of the recordings from the occupied survey point on Anacapa (ANI04_01) and found an additional 20 ASSP vocalizations that had been missed by XBAT. Thus the automated detection process detected 54 of a total of 74 calls (73%) available for detection on recordings from this site. This matched our initial estimate of 75% sensitivity for the search template based on its detection performance on a standard reference dataset (see Methods).

Finally we searched for undetected ASSP calls on a randomly selected sample of 10% of the recordings from each of the 11 survey periods that had not detected ASSP activity. We did not find any undetected ASSP calls. We also searched for the vocalizations of Leach's Storm Petrels and did not find any calls for this species.

**Additional species detected acoustically**

We conducted a separate search for Leach's Storm-Petrel (*Oceanodroma leucorhoa*) vocalizations on the acoustic recordings from Anacapa Island, and failed to find any calls from this species.

Cassin's Auklet (*Ptychoramphus aleuticus*) vocalizations were detected at survey site A-4 on West Anacapa Island (Portuguese Rock) in both survey years. Cassin's Auklets are another nocturnal, hole-nesting seabird species expected to benefit from the removal of black rats from the island.

## Discussion

Automated acoustic sensors contributed vital data to the Ashy Storm-Petrel surveys on Anacapa Island. These passive sensors greatly increased the temporal scale of the survey effort in difficult terrain and helped field staff focus more intensive search efforts in areas with ASSP activity. This led to the discovery of the first nest record for Ashy Storm-Petrels on Anacapa.

The detection of Ashy Storm-Petrel vocalizations in both years, and the discovery of an active burrow in 2012 strongly suggest the presence of an Ashy Storm-Petrel breeding aggregation at Portuguese Rock (A4), West Anacapa Island (*Figure 2-1*). Mean rates of vocal activity at Portuguese Rock did not differ significantly between 2011 and 2012 (***2011***= 0.09 calls per minute +/- 0.14 s.d. and ***2012*** = 0.06 calls per minute +/- 0.17 s.d.; $t=0.64$, $df=28$, $p > 0.20$).

Acoustic activity rates have been found to be significantly correlated with measures of burrow densities within 50m of acoustic sensors for two other seabird species – Forster's Tern (*Sterna forsteri*) (Borker et. al.; Pers Comm), and Wedge-tailed Shearwater (*Puffinus pacificus*) (McKown et al.; Unpublished data). These results suggest that acoustic indices can be an effective metrics for monitoring long-term trends at seabird breeding sites. We have not been able to compare Ashy Storm-Petrel activity rates to nest densities to date largely because of the challenges associated with finding and counting storm-petrel breeding burrows. However, preliminary data from Southeast Farallon Island show that acoustic metrics (mean Ashy Storm-Petrel calls per minute) agree with qualitative estimates of storm-petrel burrow abundance at six survey sites on the island (McKown et al. Unpublished data). That is, Ashy Storm-Petrel call rates are high in areas thought to contain high numbers of Ashy Strom-Petrel breeding burrows, intermediate in areas thought to contain low numbers of breeding burrows, and low or absent in areas where breeding burrows have never been found. Further research to confirm this relationship could be carried where there are good estimates of breeding burrow densities.

In 2012, Ashy Storm-Petrel calls were detected at the site as early as March 29 and continued regularly until the sensor failed on July 24, 2012.

No Ashy Storm-Petrel vocalizations were detected at any of the other 23 acoustic survey sites on Anacapa Island in 2011 or 2012. Based on the results of a re-sampling routine (*Figure 2-5*) of detection data from 2012 Portuguese Rock, we estimated that the acoustic survey effort undertaken for this project had more than a 95% chance of detecting Ashy Storm-Petrel calls from breeding aggregations similar to the A4 survey site (Portuguese Rock site). Our data show that the longest period of consecutive nights without a detection at survey site A4 was 9 nights (after April 1). Prior to April 1 there was a 24-day stretch without call detections in early March, but Ashy Storm-Petrels may not have been present on the island at that time. Thus, similar levels of Ashy Storm-Petrel activity would likely have been detected at the 22 survey sites on Anacapa with more than 9 nights of survey effort had it been present.

Although this resampling exercise suggests that an optimal acoustic survey period to detect the presence or absence of Ashy Storm-Petrel on Anacapa Island may be between 10 nights and 14-nights, we still recommend a minimum one-month per site period for future surveys (*Figure 2-5*). Ideally a month-long survey period could greatly increase the chances of detecting very small breeding aggregations while also mitigating potential sampling error introduced by stormy nights and attendance patterns related to the lunar cycle. Finally, once breeding locations are identified, longer survey periods (i.e. season-long) at occupied sites can help provide the statistical power needed to detect year-to-year trends in long-term monitoring efforts.

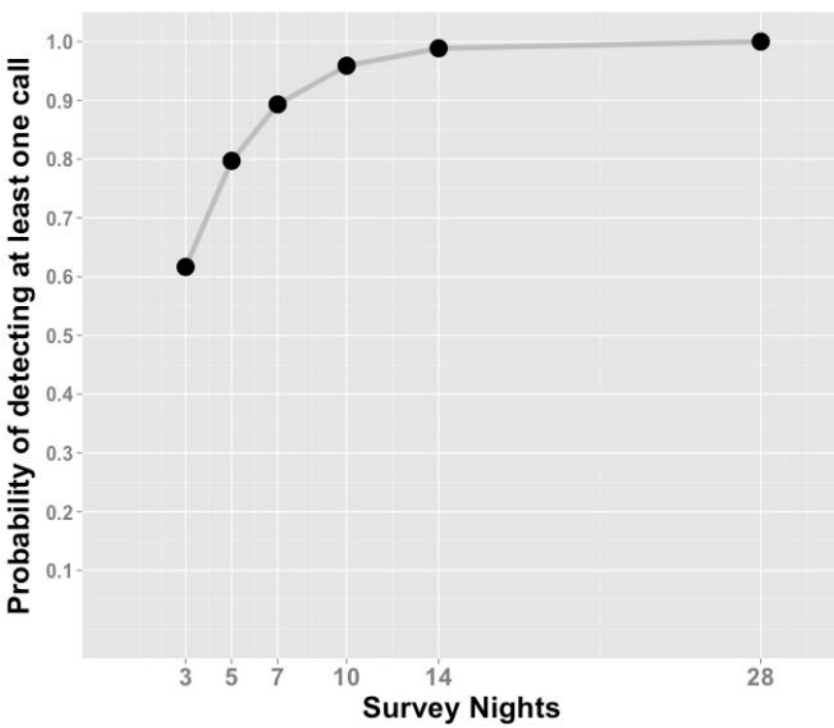


***Figure 2-6*** ***Probability of detecting at least 1 Ashy Storm-Petrel call given a random sample of survey nights (e.g. 3, 5, 7, 10, 14, 28 survey nights). Data points represent the mean of 1000 random sample permutations selected from the 2012 data recorded at Portuguese Rock. For example, 80% of the time, random samples of 5 survey nights contained at least 1 Ashy Storm-Petrel call.***

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