Alcid Habitat Restoration and Xantus's Murrelet Nest Monitoring on Santa Barbara Island, California in 2007

A. Laurie Harvey and Kevin W. Barnes

Montrose Settlements Restoration Program
Channel Islands National Park
1901 Spinnaker Drive
Ventura, CA 93001
laurie_harvey@nps.gov

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ABSTRACT

Santa Barbara Island supports significant colonies of both surface- and crevice- nesting birds. However, anthropogenic disturbances, including the introduction of nonnative species, devastation to native plant communities, and impacts due to marine contaminants, have heavily impacted nesting seabird colonies. To help offset such impacts on seabirds, the Montrose Settlements Restoration Program began habitat restoration work in 2007 to benefit Xantus's Murrelets and Cassin's Auklets on Santa Barbara Island. Project goals in the first year of this alcid habitat restoration project were to: (1) perform baseline monitoring of Xantus's Murrelets nesting on Santa Barbara Island; (2) design and construct an on-island plant nursery; and (3) complete a small pilot outplanting to identify plant growth and survivorship and to facilitate planning for future restoration work. We conducted nest monitoring for Xantus's Murrelets at five locations in 2007 to establish baseline breeding data for future assessment of restoration actions. Nesting phenology in 2007 was protracted; egg-laying occurred from early March through early July. The earliest hatching occurred in early April, with peak hatching in late June; the last nests of the season hatched by late July. Hatching success at the long-term Cat Canyon study site was comparable to the 1993-2003 mean (HS=63%; n=24 active nests). However, analysis of Cat Canyon data using the greatest sample size available resulted in a lower estimate of nesting success, suggesting the plot-based monitoring should be expanded (HS=54%; n=39). Overall hatching success in the Northeast locations was comparable to that of Cat Canyon (HS=61%; n=31). We conducted pilot habitat restoration work at four sites in 2007. We started seed propagation in late January using native seed stock collected on Santa Barbara Island. Nine native plant species were grown and transported to the island by boat and housed in an on-island growing facility. Restoration site selections were based on known nesting distributions and habitat preferences; outplantings were completed at fixed densities and were individually tagged to determine survivorship. Restoration areas will be monitored annually for evidence of new nesting by Xantus's Murrelets and Cassin's Auklets.

INTRODUCTION

Santa Barbara Island (SBI), situated approximately 40 miles offshore mainland California, is the smallest and southernmost of the five islands in the Channel Islands National Park (CINP). Significant colonies of both surface- and crevice-nesting seabirds exist on the one square mile island and its offshore islets, partly due to the absence of large, non-avian predators (Hunt et al. 1980, Carter et al. 1992, McChesney and Tershy 1998, Whitworth et al. 2003). SBI hosts over 50% of the U.S. nesting population of the state-threatened Xantus's Murrelet (*Synthliboramphus hypoleucus*, XAMU), representing perhaps 20% of the global population of this rare bird's breeding individuals (Carter et al. 1992, Burkett et al. 2003, Whitworth et al. 2003). However, anthropogenic disturbance of the ecosystem on SBI has been widespread, and seabird colonies were heavily impacted, and in some cases extirpated, by introduced predators. Similarly, native plant communities that support nesting alcids have yet to recover from the "devastation of native shrubs and succulents, and, in some areas, removal of all plant cover" and associated invasive plant introductions resulting from military and farming activities during the last century (Halvorson 1994).

Feral cats (*Felis cattus*) were numerous on the island until the late 1970s and apparently were responsible for the extirpation of the previously large Cassin's Auklet (*Ptychoramphus aleuticus;* CAAU) colony on SBI (Willet 1912). Historic records from the 1800s indicate that burrows were "numerous" on SBI in 1863 and "had undermined almost every part of the soft, earthy surface" (Cooper 1873, Cooper *in* Howell 1917). Similarly, in 1897 CAAU were reportedly "breeding in large numbers" (Grinnell 1897). Two years later, a June visit to SBI noted many auklet nests on the "southern end, where the higher land slopes gradually towards the cove" and the author had "no doubt that the birds nested elsewhere on the island" (Robertson 1903). However, by 1908 there was "no indication" of nesting on SBI (Howell 1917), and in June 1911, Willet (1912) found that the colony on Santa Barbara Island proper had been "exterminated by the cats with which the island is infested", but noted a colony of about 100 pairs on Sutil Island. The following year, "a thorough search of the northwest end of Santa Barbara netted nothing but the wings of those birds whose bodies had been eaten, probably by cats", and while Sutil Island was not checked, the authors concluded that the Cassin's Auklet colony remained confined to that offshore islet (Wright and Snyder 1913). More recent surveys found about 75 nests on SBI proper in 1977 (Hunt et al. 1980), but by the 1990s only a few nests persisted on the western side of the island and no nesting has been documented in recent years (MSRP 2005).

While feral cats were apparently the major direct threat to seabirds on SBI until their removal (in 1978; Murray et al. 1983), widespread changes in the island ecosystem likely still limit recolonization by auklets and colony expansion by murrelets. Habitat degradation on SBI was undoubtedly accelerated by the introduction of herbivorous animals [e.g. European rabbits (*Oryctolagus cuniculus*) and sheep (*Ovis aries*)] and subsequent over-grazing of native vegetation (see Burkett et al. 2003 for summary of anthropogenic impacts). Halvorson (1994) identified the vegetation of Santa Barbara and

San Nicolas Islands as the "most seriously impacted" of the Channel Islands in terms of nonnative species introductions and associated erosion areas. Such changes in plant community structure likely continue to affect the Xantus's Murrelet and the Cassin's Auklet through decreases in adequate nesting sites and in cover from aerial predators. In particular, a significant proportion of Xantus's Murrelet nest sites on SBI are found in association with native shrubs (Roth et al. 1999, Burkett et al. 2003, Whitworth et al. 2003). Alteration of shrub and soil composition may compromise the ability of prospecting Cassin's Auklets to excavate structurally sound burrows on the island.

To help offset population-level impacts on seabird populations resulting from DDT contamination, the Montrose Settlements Restoration Program (MSRP) prioritized habitat restoration work to benefit Xantus's Murrelets and Cassin's Auklets on Santa Barbara Island. Project goals in the first year of the alcid habitat restoration project were as follows: (1) perform baseline monitoring of Xantus's Murrelets nesting on SBI; (2) design and construct an on-island plant nursery; and (3) complete a small pilot outplanting to identify plant growth and survivorship and to facilitate planning for future restoration work. We report here baseline Xantus's Murrelet monitoring in 2007 with comparison to previous nest monitoring data, pilot plant habitat restoration work in 2007, and recommendations for future project activities.

METHODS

XANTUS'S MURRELET NEST MONITORING

Xantus's Murrelet reproduction on SBI has been monitored annually by CINP staff and collaborators since 1983 (Schwemm et al. 2005). Two study plots were established to determine nesting phenology and to estimate colony productivity. The Nature Trail (NT) plot is located along the northeastern-facing slopes of the island immediately to the south of the NPS housing. The Cat Canyon (CC) plot is located on the steep slopes between Signal Peak and Cat Canyon at the southernmost end of the island. In addition to these study plots, murrelet nests surrounding the housing and dock areas, as well as a small number of nest boxes, have been monitored regularly (Roth et al. 1999, CINP unpubl. data).

In 2007, we continued the long-term monitoring at the study plots described above (NT, CC, House, and Dock). In addition, we monitored all active sites found along the northeast-facing Landing Cove (LACO) slopes, where nesting had been previously recorded (Carter et al. 1992, Whitworth et al. 2003). Due to logistical constraints resulting mainly from limited staff and transportation (boats were normally available just once per week) as well as unpredictable weather, we were unable to monitor on a five-day interval schedule as had been done in most, though not all, years (Roth et al. 1999, Schwemm and Martin 2005, P. Martin pers. comm.). Therefore, sites typically were monitored at 5 and 10-day intervals beginning on 5 March and ending when the last eggs of the year were found hatched on 8 August 2007.

The CINP seabird monitoring program historically reported occupancy and hatching rates from long-term ("historic") sites in NT and CC (n=52 and 71-74 historic sites in NT and CC, respectively; Murray et al. 1983, Roth et al. 1999, Schwemm and Martin 2005). Additional sites were tagged by other researchers over time. In 2007, we monitored all accessible sites in these plots including all additional potential sites found in pre-breeding season searches. Of the historic sites in the CC plot (sites 1-71, 99, 151, 155), six (sites 66-71) were not accessible due to close proximity of nesting California Brown Pelicans (*Pelecanus occidentalis californicus;* BRPE). Additionally, several of the tags (#1, 4, 5, 6, 7, 18, 25, and 30) could not be located. These sites were likely checked during the course of the nesting season as all available habitat was searched, including some crevice sites that were obviously previously monitored (e.g. as indicated by remnants of tags or nails). Each unmarked site was tagged and GPS positions recorded to identify which, if any, of the historic sites they represented. However, GPS data for historic sites have not yet been obtained from previous researchers. For interannual comparisons of Cat Canyon historic sites, we therefore present here data only from those sites confirmed to have been part of the long-term plot; all other sites ("non-historic") were analyzed separately.

2007 Nesting Data Collection and Analysis

Since murrelet chicks depart the nest site within 3 days after hatching (Murray et al. 1983), reproductive success is most accurately measured by hatching success rather than fledging rate. Two measures of hatching success are reported here: (1) productivity, or number of eggs hatched per nest attempt, and (2) hatching success as defined in Whitworth et al. (2005), where nest attempts with at least one hatched egg were considered successful. For sites with more than one attempt, the ultimate outcome of the nest site was reported for reproductive success (e.g. if the first attempt failed but a relay attempt hatched at least one egg, that nest was classified as successful). In the event that more than one clutch hatched successfully from a single site, both attempts were included in hatching success and productivity calculations.

Egg fates were categorized as one of the following: hatched, depredated, broken, disappeared, abandoned, addled/not hatched, or fate unknown. Hatching was confirmed by either the presence of chicks, hatched eggshell fragments (indicated by paper-like, detached membranes), or by a sufficient incubation period (>35 days) followed by egg disappearance. Depredation rates were calculated as the percentage of eggs laid that were depredated (identified by a shiny, intact membrane and small tooth marks on the broken eggshells; see Schwemm and Martin 2005). In contrast, eggs apparently damaged by fallen rocks (evidenced by small star cracks or obvious rock fall in the site) were classified as broken (this category was not previously used in CINP data records). However, eggs were classified as abandoned if left unattended prior to clutch completion or for more than fifteen days thereafter, even if eggs were subsequently depredated by mice. Eggshell fragments were removed during the course of surveys to ensure accurate egg count data.

Percent occupancy (the proportion of long-term sites that were active during the year) was reported for historic sites only in the CC study plot. Because many of the historic

NT site markers were missing, likely due in part to shrub mortality, we were not able to obtain sufficient data to provide a reliable occupancy rate the NT plot. Occupancy was not calculated for the LACO, House, or Dock areas because few individual nest sites have been tracked over time.

Phenology calculations followed those described in Whitworth et al. (2005), where dates of egg laying and hatching were estimated based on duration between surveys and on average timing of breeding (after Murray et al. 1983). We reported minima, maxima, means, and standard deviations for clutch initiation (the estimated date the first egg of the clutch was laid) and hatching dates. Initiation and hatching data from sites with more than one attempt per year were analyzed separately.

Analysis of Cat Canyon Historic Site Data, 1993-2003

Historic nest data from the 71 historic sites in the Cat Canyon monitoring plot (described above) were converted to the hatching success parameter described in Whitworth et al. (2005) for the 1993-2003 period. Site data were not available to the authors for the years 2004-2005; no monitoring was conducted in 2006 due to the island's closure to protect extensive nesting by BRPE. Data were compiled from CINP files (original field notes; assistance from P. Martin). Productivity (eggs hatched per nest attempt) and depredation rates (number of eggs depredated per number of eggs laid) for 1993-2002 were reported in Schwemm and Martin (2005) and summary statistics from their work are presented here for comparison with 2007 data.

PILOT RESTORATION SITES

Restoration Site Selection and Surveys

We identified revegetation sites for XAMU and CAAU based on known nesting distributions and habitat preferences. Two "murrelet plots" (Prohibition Point and Arch Point), one "auklet plot" (North Peak), and one plot containing habitat for both species (Landing Cove) were surveyed in fall-winter 2007. Plots were divided into staked quadrats. We estimated total percent cover of native and non-native plant species via visual surveys by two observers within each quadrat prior to planting. We documented the relative contributions of bare ground, native species, and exotic species to percent cover in each plot, and noted presence/absence of individual species. Fall surveys were mainly limited to perennial species as they were conducted prior to the winter rains.

Baseline surveys were conducted prior to outplanting on the following dates: Prohibition Point on 13 and 27 September 2007; North Peak on 15 October 2007; Landing Cove on 11 December 2007; Arch Point on 6 January 2008. Overview photographs of each site were taken before and after planting. Outplanting took place between mid September 2007 and March 2008 with assistance from volunteer field crews. Plants were randomly spaced within quadrats at fixed densities and were individually tagged for future growth and survivorship measurements. Survival and growth data will be collected in winter 2008-2009 and will be presented in future reports. Social attraction to encourage reestablishment of the CAAU colony is planned for winter 2008.

Plant Propagation
We began seed propagation in late January 2007 at the CINP greenhouse in Ventura, CA using native stock previously collected on SBI (S. Chaney, pers. comm.). Nine species were sown: coreopsis (*Coreopsis gigantea*), silverlace (*Eriophyllum nevinii*), Santa Barbara Island buckwheat (*Eriogonum giganteum* var. *compactum*), tarweed (*Hemizonia clementina*), suaeda (*Suaeda taxifolia*), sage (*Artemisia nesiotica*), yarrow (*Achillea millefolium*), purple needlegrass (*Nasella pulchra*) and coyote bush (*Baccharis pilularis*). Additionally, boxthorn (*Lycium californicum*) individuals were successfully propagated from cuttings in spring 2007. Propagation methods varied by species and followed those established by the CINP. In general, seeds were stratified under moist conditions for approximately one week, after which individual flats were sown. Seed germination rate and success varied by species, but seedling germination and survivorship were very high for six of the eight species. To prepare for on-island propagation, a growing facility was constructed on SBI in April-May 2007.

Seedlings were transplanted into small containers in prior to being transported by boat to the nursery on SBI in May 2007. All plants were chemically treated for slugs, snails, insects, and pre-emergent weeds prior to transport; container media were cleaned and visually inspected following CINP protocols (S. Chaney, pers. comm.). Once on the island, plants were irrigated and transplanted into one-gallon containers using sterile potting soil during summer 2007 in preparation for fall outplanting. The small 20' x 20' island nursery was originally designed to hold approximately 1,000 plants. However, plant survivorship on the mainland was much higher than expected, and by July the nursery contained approximately 2,000 plants, which were moved to the island in two shipments during the early summer.

Prevention of Non-Native Introductions
While strict treatment protocols to prevent potential introductions were observed (discussed above), the common garden slug (*Milax gagates*) was inadvertently transported to the island with plant materials. In addition to current monitoring protocols to ensure slugs did not spread from the nursery area, an island-wide survey of invertebrates is planned for 2008 in collaboration with the Santa Barbara Natural History Museum. To prevent future issues associated with transporting plant material from the mainland, we will discontinue the mainland growing phase. All plant propagation will take place on-island beginning in 2008 to remove the potential for contamination from mainland facilities.

Climate
Precipitation data were collated from the CINP weather station (online data maintained by Western Regional Climate Center) except where no data were available; precipitation data for September 2007-May 2008 were obtained from the island log maintained by CINP and MSRP staff and volunteers. We report data for calendar years and monthly totals for "rainy seasons" (1 September through 31 May).

RESULTS

NEST MONITORING DATA

Cat Canyon Hatching Success and Occupancy, 1993-2003

We calculated hatching success (percent of active nests that hatched at least one egg) from the Cat Canyon historic plot data to permit direct comparisons of long-term reproductive performance among colony sites (e.g. Anacapa Island; see Whitworth et al. 2005; Table 1). Annual hatching success (HS) from 1993-2003 ranged from 48-91%, with an overall mean HS of 68% (Table 1, Figure 1). Mean occupancy was 46% (± 9%), equivalent to about 32 active nests per year.

The number of monitored sites varied among years due mainly to the presence of nesting Brown Pelicans (CINP unpubl. data, P. Martin pers. comm.). However, analysis of the time series using site data limited to that of the lowest available sample size yielded similar results for both the overall 11-year mean hatching success and occupancy rate: HS=68% (± 16%) at n=22 per year; occupancy = 45.3% (± 10%) at n=61 per year.

Table 1. Occupancy and hatching success, 1993-2003, in the Cat Canyon plot from historic sites only.

Year	Monitored Sites	Occupied Sites	Occupancy Rate	Total Nests	Hatched Nests	Hatching Success
1993	71	42	59%	42	31	74%
1994	71	38	54%	38	20	53%
1995	69	27	39%	27	16	59%
1996	71	31	44%	31	19	61%
1997	71	32	45%	31	15	48%
1998	71	33	46%	33	26	79%
1999	71	44	62%	44	29	66%
2000	71	28	39%	28	21	75%
2001	61	22	36%	22	20	91%
2002	70	23	33%	22	11	50%
2003	71	32	45%	32	29	91%
Mean	**70**	**32**	**46%**	**32**	**22**	**68%**

Cat Canyon Hatching Success, Occupancy, and Phenology, 2007

We monitored 158 potential sites in the Cat Canyon plot, of which 57 were classified as historic sites (Table 2). Historic site occupancy in 2007 was 46%, or 26 nests (see methods for discussion of sample sizes), with an additional 16 active nests in "non-historic" sites. Of the 42 active sites, ten nests (nearly 25%) contained second attempts after initial failure.

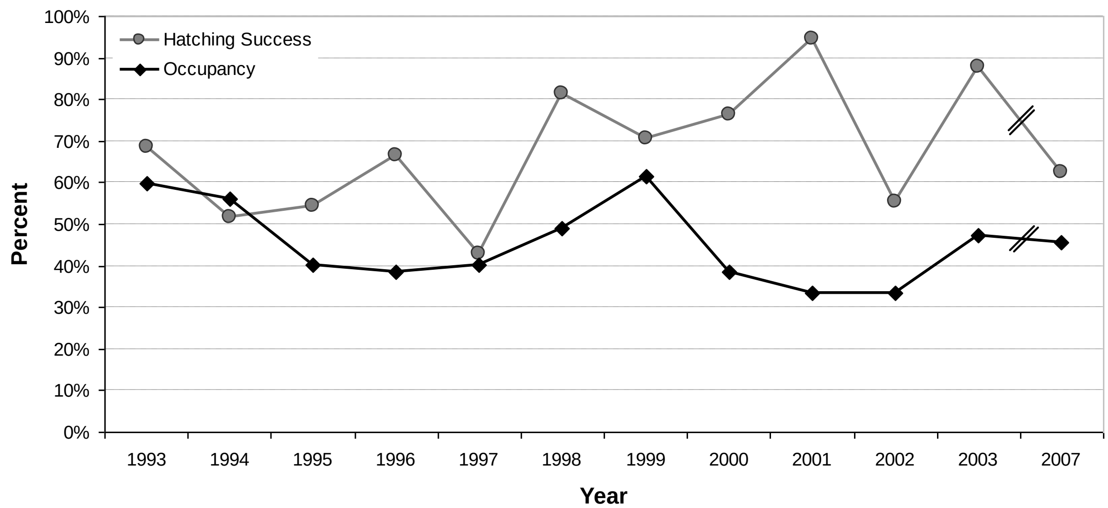

Figure 1. Hatching success and occupancy at Cat Canyon historic sites from 1993-2007.

We determined clutch sizes for 40 nest attempts; 33% (13 attempts) contained single-egg clutches, most of which were depredated before clutch completion (Table 2). The remainder (27) contained two-egg clutches. We estimate that between 79 and 91 eggs were laid in 52 total attempts. This range reflects the possible presence of a second egg in nests where clutch size was unconfirmed.

A total of 45 eggs were depredated, representing 58% of eggs laid (n=77 eggs with known fates; Tables 2, 3). The egg depredation rate for historic sites in 2007 was 55%; this figure was higher than published rates in all years from 1993-2002 except that observed in 2002 (62%; the 1993-2002 mean = 37% ± 14%; Schwemm and Martin 2003), indicating that a very high level of predation occurred in 2007.

In 2007, hatching success from historic sites was 63%; and productivity was 0.76 eggs hatched per nest attempt. Both statistics were only slightly lower that the 1993-2003 means (HS=68%; Table 1, 2; Figure 1; productivity=0.80 ± 0.25; Schwemm and Martin 2003).

Hatching success for all non-historic sites (n=15) was 40%, much lower than from historic sites only (n=24; Table 2). Similarly, productivity for non-historic sites was a very low 0.36 eggs hatched per nest attempt as compared to 0.76 in historic sites.

Nesting phenology in 2007 was protracted, with clutch initiations occurring over a nearly four month period from 2 March to 29 June (Figure 2, Table 4). Though the first peak in initiation occurred in mid March, early nest failures were followed by a relatively high percentage of relay attempts with two late-season peaks (late May and late June). As a result, the overall mean clutch initiation date occurred in early May, although few nests were actually initiated in this period. The earliest nests hatched in mid April, with peak hatching in late June; the last nests of the season hatched by mid July (Table 5).

Table 2. Xantus's Murrelet nest monitoring results at Cat Canyon in 2007.

Parameter	Historic Sites	Non-Historic Sites	All Sites
Total monitored	57	101	158
Total active	26	16	42
Total successful	15	6	21
Second attempts	19%	31%	24%
Occupancy	46%	16%	27%
Depredation rate[1]	55%	63%	58%
Productivity (n)[2]	0.76 (25)	0.36 (14)	0.62 (39)
Hatching success (n)[3]	63% (24)	40% (15)	54% (39)

[1]Depredation rate as total eggs depredated per total eggs laid.

[2]Productivity as total eggs hatched per nest attempt; parentheses indicate sample size for calculations.

[3]Hatching success as at least one egg hatched per nest attempt.

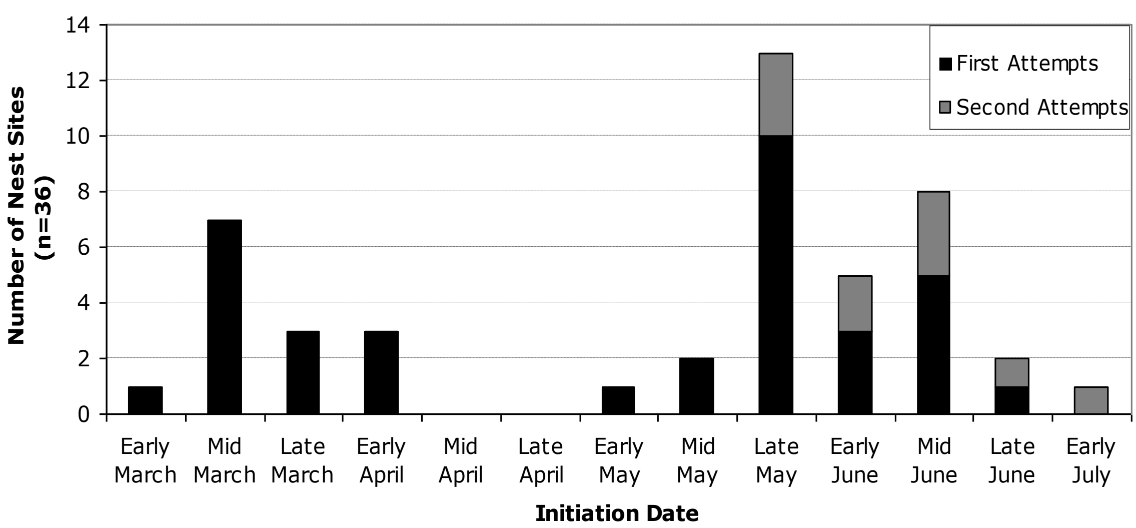

Figure 2. Xantus's Murrelet clutch initiation dates for all nest attempts at Cat Canyon in 2007.

Table 3. Cat Canyon egg fates from all active sites in 2007.

Nest Attempt Status	First Attempt	Second Attempt	All Attempts
Eggs laid	60	18	78
Eggs hatched	20	4	24
Depredated eggs	33	12	45
Broken eggs	2	0	2
Abandoned eggs	2	0	2
Disappeared eggs	3	1	4
Unknown fates	0	1	1

Table 4. Cat Canyon clutch initiation dates in 2007.

Initiation Date	First Clutch	Second Attempt	All Attempts
Earliest	2 March	21 May	2 March
Latest	21 June	29 June	29 June
Mean	1 May	9 June	9 May

Table 5. Cat Canyon hatching dates in 2007.

Hatching Date	First clutch	Second Attempt	All Attempts
Earliest	14 April	6 July	14 April
Latest	15 July	6 July	15 July
Mean	25 June	6 July	26 June

Northeast Island Sites: Nature Trail, Landing Cove, House, and Dock
In 2007, we were able to find just 31 of the 52 tags from previous monitoring efforts at NT. We monitored 11 of these sites regularly throughout the nesting season (site numbers 1-11, comprised wholly of rock crevice habitat). The rest of the sites were located in the lower portion of the plot, which exclusively consisted of shrub habitat, at least 11 of which appeared to provide unsuitable nesting habitat. These sites were excluded from monitoring for the remainder of the year due to proximity of nesting BRPE along the plot edges. Additionally, the lower portion of this plot is an unstable, precipitous slope unsuitable for monitoring except by experienced teams of researchers.

Our resulting NT sample size was very low at just four active nest sites; second attempts were initiated in three sites (Table 6). Productivity (0.40) and hatching success (40%) were also very low, though the small sample size made interpretation difficult. Two attempts were abandoned with eggs subsequently depredated by mice; three attempts failed after mouse depredation, and two attempts hatched at least one chick.

Table 6. Nest monitoring results from the Northeastern sites in 2007.

Parameter	Nature Trail	Landing Cove	House	Dock	Totals
Total active	4	7	9	10	30
Total successful	2	4	6	7	19
Second attempts	75%	14%	0	30%	23%
Depredation rate[1]	38%	0	0	26%	30%
Productivity (n)[2]	0.40 (5)	0.86 (7)	1.40 (8)	0.80 (10)	0.90 (30)
Hatching Success (n)[3]	40% (5)	57% (7)	67% (9)	70% (10)	61% (31)

[1]Depredation rate as total eggs depredated per total eggs laid.

[2]Productivity as total eggs hatched per nest attempt; parentheses indicate sample size for calculations

[3]Hatching success as at least one egg hatched per nest attempt.

To increase the XAMU sample size along the Northeastern area of the island, we monitored all potential habitat (composed entirely of shrub sites) on the northeastern-facing slopes above Landing Cove. A total of seven active nests were tracked throughout the season; these nests ultimately had very high productivity (0.86 egg hatched per attempt) and moderate hatching success (57%; Table 6). Mouse depredation was minimal, with just two depredated eggs in the LACO sites, both of which had been previously abandoned.

Nesting data from sites in the House and Dock areas have been historically analyzed separately from the CC and NT plots because of obvious differences in direct anthropogenic impacts (see Roth el al. 1999). However, in 2007, the 19 active sites in the house (n=9) and dock (n=10) areas had relatively high productivity (1.40 and 0.80, respectively) and hatching success (67% and 70%, respectively) with associated low depredation rates (zero at the nine house sites and 26% at the 10 dock sites; Table 6). Two of the seven nest boxes located beneath the pier (B9 and B14) were active in 2007 (included in the Dock analysis; Table 6). Interestingly, five of the eggs laid in the dock area (26%) failed to hatch following a sufficient incubation period.

We combined phenology data for the Northeastern sites because of the small sample sizes and geographic proximity. Two main peaks of initiation occurred, with the majority of first clutches laid in mid March and a second peak in late May (Table 7, Figure 3). Initiations commenced on 13 March, latest initiation occurred on 19 July, and mean clutch initiation occurred on 7 May. Hatching occurred between early April and late July; mean hatching occurred in mid June (Table 8).

Table 7. 2007 Xantus's Murrelet clutch initiation dates at Northeastern sites.

Initiation Date	First Clutch	Second Attempt	All Attempts
Earliest	13 March	22 May	13 March
Latest	20 June	19 July	19 July
Mean	24 April	11 June	7 May

Table 8. Xantus's Murrelet hatching dates at the Northeastern sites in 2007.

Hatching Date	First Clutch	Second Attempt	All Attempts
Earliest	9 April	2 July	9 April
Latest	7 June	23 July	23 July
Mean	23 May	19 July	15 June

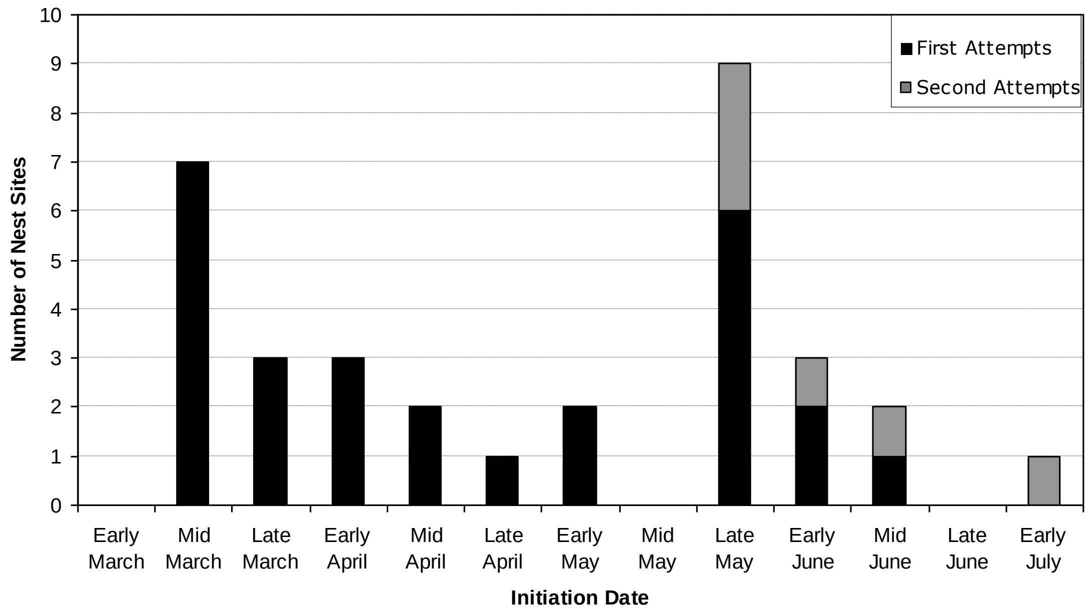

Figure 3. Xantus's Murrelet phenology at the Northeastern sites in 2007.

Additional Surveys

To further explore Xantus's Murrelet habitat utilization, we searched vegetation and crevices at the following locations: (1) shrub habitat among crevice sites in Cat Canyon; (2) cliff edges above Landing Cove; (3) rocky areas atop Arch Point; (4) north end cliffs; (5) slopes below Signal Peak (south and west slopes); (6) Webster Point Cliffs. Nesting had been previously recorded in these locations (Carter et al. 1992, Whitworth et al. 2003). Murrelets were found nesting in small numbers in all areas containing suitable habitat (e.g. presence of rock crevices and/or large shrub habitat in close proximity to cliff edges). In general, rock crevices appeared to be less structurally complex, shallower in depth, and more sparsely distributed than those found at other sites (e.g. Anacapa Island and Coronado Islands; Whitworth et al. 2005, Carter et al. 2006). Nest dimensions were recorded for possible future comparisons with other sites. We documented nest sites beneath Santa Barbara Island buckwheat, silverlace, tarweed, and boxthorn shrubs, as found by previous researchers (Murray et al. 1983, Carter et al. 1992, Drost and Lewis 1995, Whitworth et al. 2003). We searched extensively for evidence of CAAU nesting throughout the year (see Whitworth et al. 2008 for descriptions). No CAAU nesting was observed in 2007 on SBI proper.

Adult Murrelet and Auklet Mortality

Adult XAMU and CAAU carcasses were found both in monitoring plot areas and during opportunistic island-wide surveys. These data will be presented in a future report with updated adult mortality data.

Avian Predator Abundance
Barn Owls (*Tyto alba*) were present on the island in 2007, but island-wide abundance surveys comparable to previous work (see Drost and Fellers 1991) were not possible due to extensive BRPE nesting. Common Ravens (*Corvus corax*) were noted just once during the murrelet breeding season.

A Peregrine Falcon (*Falco peregrinus;* PEFA) nest was confirmed on SBI in 2007, the first successful nest documented on SBI since they re-occupied the island in 1995 (B. Latta pers. comm.). We inspected the eyrie, located on the steep southern cliff below Signal Peak, on 19 April 2007 and found three chicks, which were subsequently banded on 9 May (aged 21 days old; Santa Cruz Predatory Bird Research Group [SCPBRG] unpubl. data). Murrelet feathers were present in the nest site, but only one of the 43 individual prey items analyzed from the feather pile collection was a XAMU. SCPBRG estimated that XAMU represented 13% of the calculated biomass of the prey remains collected from the SBI nest (SCPBRG unpubl. data). In comparison, XAMU represented 6.7% of the total biomass of combined prey remains collected from a comprehensive PEFA survey of the Channel Islands in 2007 (SCPBRG unpubl. data).

PILOT RESTORATION SITES

Four areas were selected for pilot restoration work in 2007 (Figure 4). The Prohibition Point and Arch Point plots, both located near exposed cliff-edge areas, were targeted for restoration to functional Sea Cliff Scrub communities to benefit murrelet nesting habitat (see Halvorson et al. 1988 for descriptions of plant communities). The more interior North Peak plot was chosen as a pilot site for auklet restoration; this area was characterized by a near-monoculture of exotic grasses and will eventually be restored to contain Coreopsis Scrub and Coastal Sage Scrub. Restoration of the Landing Cove plot will proceed along a continuum between Sea Cliff Scrub, Coreopsis Scrub and Boxthorn Scrub as the distance from the cliff edge habitat increases; restoration in this area may enhance habitat for both murrelets and auklets. We focus here on preliminary results from two areas: the Prohibition Point XAMU plot and the North Peak CAAU plot (Figure 4). Results from the Landing Cove and Arch Point plots have not yet been assessed and will be presented in a future report after survivorship survey data are compiled.

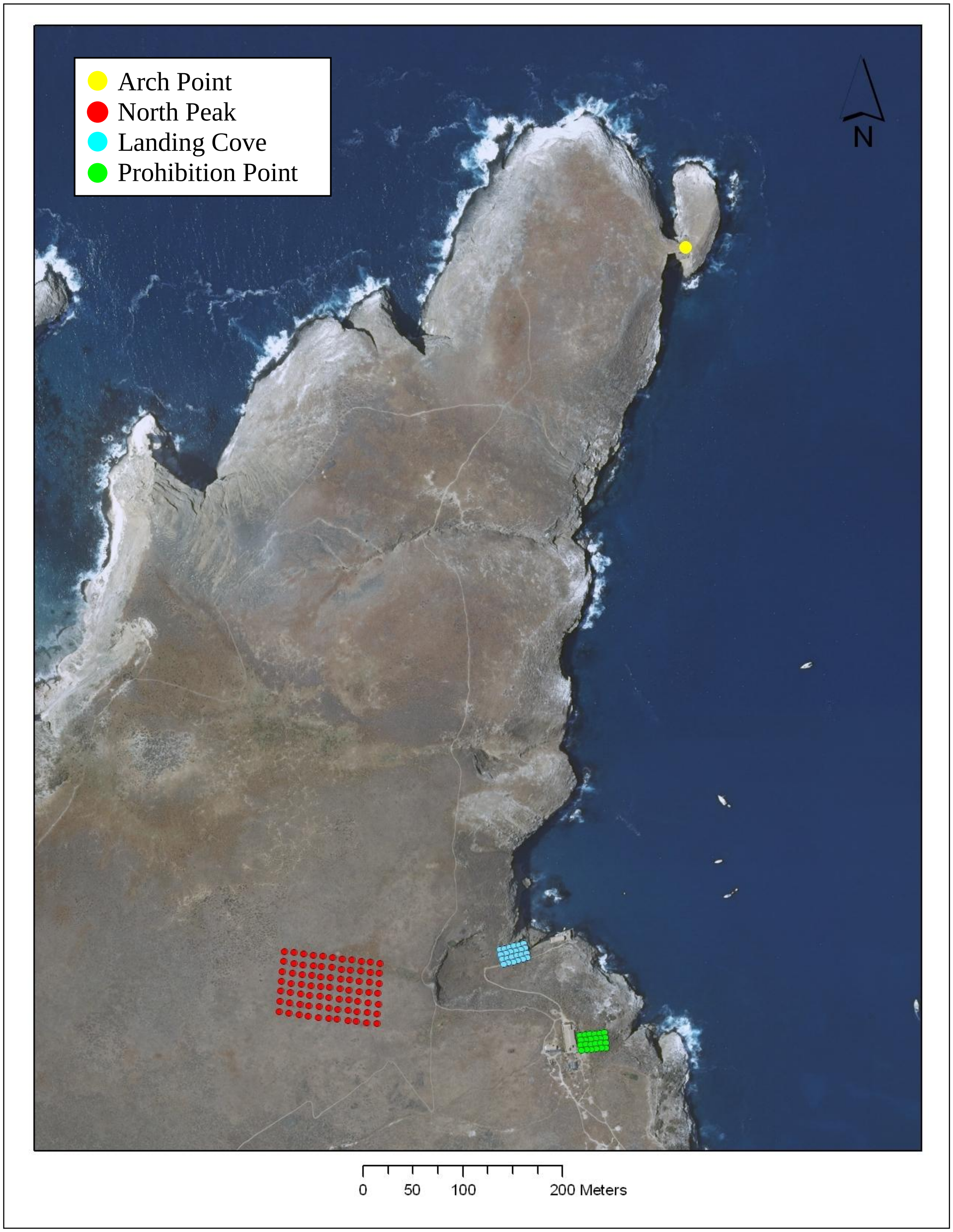

Figure 4. Locations of Prohibition Point, North Peak, Landing Cove, and Arch Point pilot planting plots in 2007.

Precipitation
Rainfall in 2007 (between 1 Jan 2007 and 5 January 2008) totaled approximately 16 cm, 33% lower than the mean of 23.73 (± 6.7cm) for calendar years 2003-2006. However, the 2007-2008 rainy season (1 September 2007–31 May 2008) totaled 25.2 cm, a marked increase over the previous two years (Table 9). The majority of precipitation fell in January and February 2008 (9.7 and 6.1 cm, respectively; Figure 5).

Table 9. Total precipitation data for rainy seasons, 2003-04 through 2007-08.

Rainy Season	Total Rainfall (cm)
2007-08	25.2
2006-07	8.1
2005-06	20.4
2004-05	39.7
2003-04	54.1

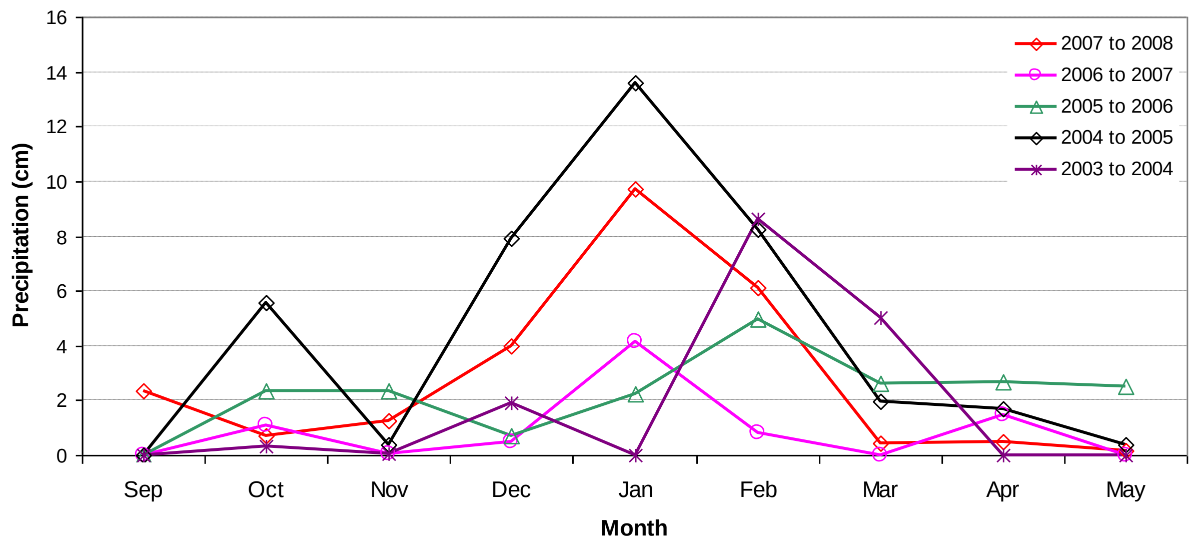

Figure 5. Monthly total precipitation at Santa Barbara Island during rainy seasons 2003-04 through 2007-08.

Prohibition Point Restoration Plot

This site is situated on a moderately steep (15-20º), east-facing slope immediately to the south of Landing Cove (Figure 4). Criteria for site selection included proximity to known XAMU nesting sites as well as a very high level of soil disturbance with associated abundance of exotic vegetation. We divided the Prohibition Point Plot into fifteen 5 x 5 meter quadrats (375 m^2). Estimates of percent cover and species composition were recorded in mid to late September 2007 prior to the first rains of the season. The plot was characterized by a high percentage of bare ground (mean 49%; Table 10) as very few perennials were present and most annuals were noted only as "dead vegetation" at the time of the survey. As a result, mean percent cover of exotic species was approximately equal to that of native cover at about 12% each (Table 10).

Table 10. Mean absolute percent cover by category in the Prohibition Point plot in September 2007.

Category	Mean (%)	SD
Bare ground	49	21
Exotic species	12	6
Native species	12	12
Bare rock	0	0
Dead vegetation/thatch	33	18

In total, 155 plants suitable for restoration of this Sea Cliff Scrub habitat (see Halvorson et al. 1988) were placed in the Prohibition Point site in late September 2007 at a density of 10 plants per 25 m^2. Silverlace, buckwheat, and suaeda were the primary species used (N=54, 55, and 36, respectively); small numbers of coreopsis, tarweed, purple needlegrass, and common yarrow also were included in this plot (Table 11). Plant sizes (width and height) were recorded at the time of planting; mean height for all species (excluding the annual species yarrow and purple needlegrass) ranged from 11 to 43 cm, and mean width ranged from 11 to 37 cm.

Table 11. Size data at time of planting for five species used in the Prohibition Point restoration area.

Species	Total Planted	Height (cm)		Width (cm)	
		Mean	SD	Mean	SD
Eriogonum giganteum var. *compactum*	55	19.4	7.6	25.9	4.4
Eriophyllum nevinii	54	19.7	7.4	25.4	5.5
Suaeda taxifolia	36	27.6	14.1	36.6	12.9
Coreopsis gigantea	3	43.2	14.1	16.1	3.9
Hemizonia clementina	3	11.0	6.4	11.0	6.4

North Peak Restoration Plot

The North Peak plot is the second of four pilot sites in which restoration was initiated in 2007. This 6,000 m^2 area is characterized by a gently sloping northeasterly aspect on the slopes between Landing Cove and North Peak (Figures 8 and 9). Baseline surveys were conducted in October 2007; vegetation at the site was dominated by annual grasses (mean total cover 90.5% ± 13%; Table 13). As noted above for the case of the Prohibition Point site, baseline surveys were conducted prior to the rainy season; hence grasses could not be identified to species and total percent cover for both native and nonnative categories included perennial species only. A total of 690 plants were planted between 25 October and 1 December 2007; planting density was approximately 10 plants per 10 x 10 meter quadrat. Sample sizes for the five species ranged from 90 to 150 individual plants (Table 14).

Table 13. Pre-restoration absolute percent cover by category in the North Peak plot (n=60 quadrats).

Category	Mean (%)	SD
Bare ground	3	6
Exotic (non-grass)	5	11
Native species	6	8
Exotic grasses	91	13

Table 14. Outplanting data by species and size at North Peak.

Species	Total	Height (cm)		Width (cm)	
		Mean	SD	Mean	SD
Coreopsis gigantea	150	34.1	6.6	29.8	5.6
Eriogonum giganteum var. compactum	170	13.4	3.4	24.2	4.7
Eriophyllum nevinii	150	17.0	3.9	24.1	5.5
Suaeda taxifolia	130	20.6	7.3	42.9	12.8
Nasella pulchra	90	nd	nd	nd	nd

Figure 6. Overview of Prohibition Point revegetation plot after first outplanting in September (top panel) and January (bottom panel). Box indicates approximate location of detail area in Figure 7.

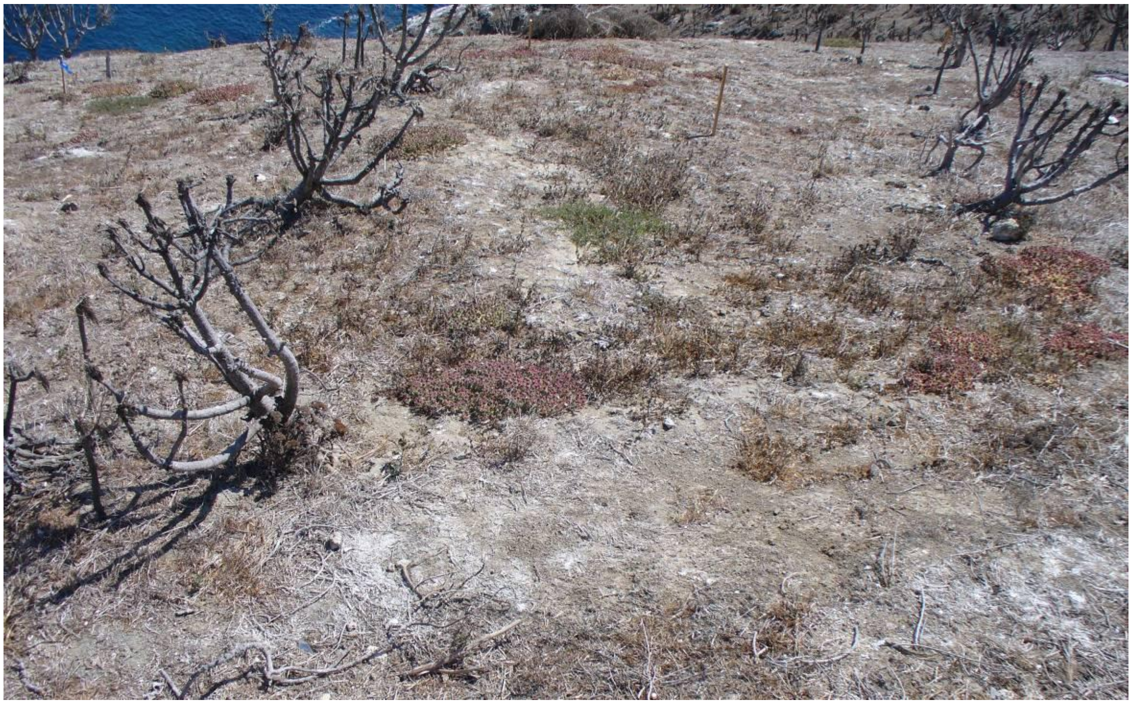

Figure 7. Prohibition Point revegetation plot before and after first outplanting, September 2007. Bottom photo shows approximately 50 plants; stakes are 5 meters apart.

Figure 8. Overviews of the North Peak plot before outplanting (top) and a representative mixed plot of coreopsis and Santa Barbara Island buckwheat.

DISCUSSION

Xantus's Murrelet Baseline Monitoring Data

The 2007 XAMU nesting season was protracted, spanning five months; the first eggs of the season were laid in early March, and the last clutch hatched in late July. At Cat Canyon, the egg depredation rate was very high at nearly 60%, and about 25% of all active nests hosted second attempts after early nest failures. In contrast, egg depredation in the Northeastern areas was a relatively low 30%. Hatching success in the long-term Cat Canyon monitoring plot was slightly depressed in comparison to the 1993-2003 mean; 63% of historic sites hatched at least one egg in 2007 compared to 68% in 1993-2003. However, overall hatching success in the Cat Canyon area for all active sites was 54%. Overall island-wide hatching success remained relatively low at 57%.

The Cat Canyon and Nature Trail monitoring plots were established to provide a standardized area from which inter-annual comparisons of nesting effort and productivity could be reliably made (Lewis et al. 1988, Roth et al. 1999). Reduced site access at both CC and NT associated with Brown Pelican nesting expansion, coupled with lack of continuity in individual site tracking, is of concern. In addition, a relatively small sample size, natural changes in habitat, differences in observer experience, use of data from only one habitat type, and exclusion of marginal sites that may be used by inexperienced breeders may bias reproductive success estimates. For example, the addition of 15 non-historic sites in the Cat Canyon study plot resulted in a nearly 10% decrease in estimated colony success. These results suggest that productivity estimates should be calculated from the maximum number of accessible sites found each year rather than from historic sites only.

The occupancy rate in historic sites at Cat Canyon was 46% in 2007, equivalent to the 1993-2003 mean. As with productivity estimates, historic nest site occupancy data may not capture actual trends in nesting effort. Occupancy calculations can only be considered a true index of nesting effort if the long-term site catalogue is representative of the entire colony and does not show changes in probability of individual site occupancy over time due to alteration of habitat, mortality of one or both members of the breeding pair (see Murray et al. 1983 for description of site fidelity), or other factors. However, occupancy rates of suitable or previously occupied sites may be useful in determining whether nesting habitat is limited and/or detecting large changes in nesting effort. We recommend that Cat Canyon site occupancy data be augmented with periodic round-island at-sea spotlight surveys that (1) sample the total breeding density of SBI proper as well as the offshore islets, (2) are not limited by changes in site composition or access, and (3) provide data comparable to work at other islands.

SBI colony success traditionally has been reported by the productivity estimate of number of eggs hatched per nest attempt(Roth et al. 1999, Schwemm et al. 2005). While important for recruitment estimates, this metric relies on the ability to determine the fates of all eggs laid. However, observed clutch sizes may represent minimum data due to egg loss before first detection and disappearance between surveys; sample sizes for productivity calculations suffer as a result. An alternate solution is to use the measure of productivity used at Anacapa Island by Whitworth et al. (2005, 2008) and elsewhere that measures hatching success as the proportion of nests that hatch at least one chick. While this is a less precise measure of productivity, it is likely more robust to error rates resulting from egg disappearance as well as to differences in survey intervals and observer experience; this parameter should be reported annually at SBI for these reasons and for comparison with monitoring work at Anacapa Island and other islands.

In summary, we recommend that annual murrelet monitoring continue because of the relatively high level of interannual variation in nesting success (Drost and Lewis 1995, Schwemm et al. 2005). Plot-based monitoring should be expanded to obtain a reliable minimum sample size for a more robust estimate of annual reproductive success and to encompass representative habitat areas for use in evaluating success of the current plant habitat restoration project. Analysis of long-term plot data should continue to compare occupancy rates in historic sites, and could be augmented by periodic spotlight surveys. Such surveys could provide an index of breeding bird numbers, which may be a favorable alternative to nest occupancy rates for determining population trends over time at this important breeding site. Obtaining representative data for XAMU reproductive success and population trends is crucial for interpreting the ultimate results of plant habitat restoration efforts.

Habitat Restoration

Plant restoration goals in 2007 focused on constructing an on-island growing facility and completing small pilot revegetation efforts. Early plant propagation took place at the CINP greenhouse in Ventura, CA; small plants were transported by boat to SBI after the on-island nursery and irrigation system were constructed. The SBI irrigation system used a solar-powered marine booster pump to draw water from a 500 gallon water storage tank to a polypipe drip system. The nursery was designed to hold approximately 1,000 plants; a larger facility will likely be required for expanded work. Plant propagation, out-planting, and nonnative plant removals are inherently labor-intensive, and SBI restoration tasks are complicated by the remote island's absence of fresh water, limited transportation to the island, and the absence of motorized vehicles with which to relocate plants to restoration areas. However, we successfully outplanted approximately 1,000 plants from gallon-sized containers between September 2007 and February 2008 with help from volunteer field crews, including an education-oriented trip for Santa Barbara City College students. The latter group incorporated the SBI restoration work into their final coursework; we intend to continue this collaboration and to expand the volunteer corps in the future.

The approximately 1.5 acres included in the four pilot restoration plots in 2007 encompass a variety of ongoing restoration challenges. For example, in the North Peak plot we seek to establish an area suitable for colonization by CAAU. This area is dominated by the exotic grass *Avena fatua*; in 2008-2009 we will expand our restoration activities to include other methods of removal (e.g. mowing) to determine the best course of reestablishing patches of native shrub habitat in the near-monoculture of oats that carpets much of the island. Alternatively, the restoration sites of benefit to XAMU are largely dominated by crystalline iceplant, sow thistle, and/or cheeseweed. Site-specific removal techniques will be tested in 2008-2009 in conjunction with additional outplantings. We expect that a minimum of three years of additional outplantings accompanied by nonnative removal will be required to reach densities suitable to maintain self-supporting native habitat in each area. Future outplanting strategies will be informed by survivorship of plants established in the winter of 2007-2008. Social attraction for Cassin's Auklets will commence in winter 2008-2009 after additional habitat restoration has been completed. Restoration areas will be monitored annually for evidence of new nesting by Xantus's Murrelets and Cassin's Auklets.

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