Scripps's Murrelet Reproductive Performance on Santa Barbara Island, California in 2008-2009

A. Laurie Harvey[1], Christine E. Hand[2], and Sasha A. Auer[3]

[1]California Institute of Environmental Studies
1901 Spinnaker Drive
Ventura, CA 93001
laurie_harvey@seabirds.org.in

[2]Carolina Department of Natural Resources
585 Donnelley Drive
Green Pond, SC 29446

[3]Ball State University
2000 West University Avenue
Muncie, IN 47306

Final Report
December 2012

Scripps's Murrelet pair during egg-laying at Santa Barbara Island, California.

Suggested citation: Harvey, A.L., C.E. Hand, and S.A. Auer. 2012. Scripps's Murrelet reproductive performance on Santa Barbara Island, California in 2008-2009. Unpublished report to the Montrose Settlements Trustee Council. 20 pages. Cover photo A.L. Harvey.

EXECUTIVE SUMMARY

- Alcid habitat restoration on Santa Barbara Island (SBI) commenced as part of the Montrose Settlements Seabird Restoration Program in 2007. Land-based nest monitoring for Scripps's Murrelet (*Synthliboramphus scrippsi;* SCMU) was conducted annually to assess island-wide reproductive performance in conjunction with plant habitat restoration.

- We monitored four study plots in 2008-2009 to assess SCMU phenology, site occupancy, and reproductive success.

- We regularly surveyed 60 active nest sites in 2008 and 75 active nest sites in 2009. Sample sizes to determine reproductive success were robust for Cat Canyon, but were small in the three Northeastern plots in both years.

- First egg-laying occurred in early March in 2008 and in early February in 2009. The 2009 nesting season was more prolonged than in 2008, lasting approximately six months from earliest egg-laying to latest hatching.

- To allow comparisons to both historic SBI data and to other colonies, we reported clutch success (the percentage of active nests that hatched at least one egg) and egg productivity (the proportion of eggs laid that hatched) for each plot.

- Clutch success was higher in 2008 than in 2009 at all monitoring locations. A high proportion of nest sites in 2009 contained more than one clutch over the course of the nesting season.

- Clutch success was substantially lower at Cat Canyon than in the Northeastern plots in both years, reaching a very low (32%) in 2009.

- Nests in the Landing Cove monitoring plot (comprised primarily of native shrub habitat) continued to show higher reproductive success than the Cat Canyon plot (comprised mainly of rocky crevice habitat).

- Egg productivity varied by location and year; lowest rates occurred at Cat Canyon in both years. Correspondingly, egg depredation rates (by native Deer Mice; *Peromyscus maniculatus elusus*) were very high at Cat Canyon. In 2008-2009, 70% and 96%, respectively, of first eggs laid in Cat Canyon failed due to mouse depredation.

- Recommendations for future work include: (1) quantifying the extent of Deer Mouse and other impacts on Scripps's Murrelet reproductive success, (2) utilizing spotlight surveys for assessing trends in colony size, (3) investigating breeding biology to determine frequency of replacement clutches in the Scripps's Murrelet, and (4) expanding surveys to better assess murrelet nesting distribution and success on SBI.

INTRODUCTION

Channel Islands National Park (CINP), located off the coast of southern California, provides critical breeding habitat for twelve seabird species (Carter et al. 1992). Many of these species were severely impacted by marine contamination following prolonged discharges of DDT off the southern California coastline (Fry 1994, Kiff 1994). In response, a lawsuit was settled in 2001 against the Montrose Chemical Corporation and other defendants; the resultant funds were placed in a trust overseen by the Montrose Settlements Restoration Program (MSRP). MSRP subsequently published a restoration plan, which identified 11 key projects of benefit to multiple species (MSRP 2005). In 2007, we began a project funded by MSRP to restore nesting habitat for Cassin's Auklets (*Ptychoramphus aleuticus;* CAAU) and Scripps's (formerly Xantus's) Murrelets (*Synthliboramphus scrippsi*, SCMU) on Santa Barbara Island (SBI; Harvey and Barnes 2009).

Santa Barbara Island is the smallest and southernmost of the islands in the CINP and supports the largest U.S. nesting colony of the Scripps's Murrelet. Over 50% of the U.S. nesting population of this state-threatened species nests on this one square mile island (Carter et al. 1992, Burkett et al. 2003, Whitworth et al. 2003, Whitworth et al. 2011). While SBI is still an extremely important breeding location for SCMU, the colony remains much reduced from historic levels (Burkett et al. 2003, Whitworth et al. 2011). Scripps's Murrelets throughout their range typically nest primarily in rocky crevices; however, on SBI, a large proportion of nests are located under native shrub habitat. Whereas all nonnative mammals (including cats, sheep, and rabbits; see McChesney and Tershy 1998 for discussion) have been removed from SBI, the native plant community structure has shown little signs of natural recovery from nonnative grazing animals and other human use (CINP unpubl. data). Native shrub habitat suitable for SCMU nesting sites continues to be confined mainly to limited cliff areas around the island's perimeter.

Land-based nest monitoring, habitat analysis, and plant restoration for SCMU have been completed annually as part of the alcid habitat restoration project. Additionally, at-sea surveys to assess CAAU and SCMU prey resources and colony trends on the island were conducted in 2008-2010 (Harvey and Barnes 2009, Whitworth et al. 2009a, 2011; Whitworth et al. in prep.). In 2008-2009, we monitored 60 and 75 SCMU nests, respectively, to determine phenology and reproductive success in the following areas: Cat Canyon, Landing Cove, House, and Dock plots. Data collection was designed to be comparable to both historic SBI data collected since the 1980s and to reproductive parameters reported for other colonies. To this end, we reported two measures of reproductive success: egg productivity and clutch success. This report provides summary results of SCMU land-based nest monitoring conducted in standardized monitoring plots in 2008-2009 for use in assessing colony status as well as the ultimate outcome of habitat restoration work on SBI.

METHODS

Data collection and logistics. Nest monitoring methods are described in Harvey and Barnes (2009) and references therein; methodology in 2008-2009 followed those previously described procedures. Briefly, nests were examined using a handheld flashlight; adults were not handled. All accessible (unattended) eggs were individually marked using a felt marker, photographed, and assigned a color identifier to assist with clutch fate determinations (murrelet egg colors often vary markedly within clutches). Beginning in 2009, nest monitoring data were recorded in the field using a PDA rather than in notebooks. Plot boundaries and individual nest site locations were mapped using handheld Garmin GPS units; position errors averaged approximately 4 meters. Monitoring schedules generally were coordinated around CINP weekly transportation (typically Wednesday boats), and seabird staff were housed in the CINP residence on SBI. In 2009, we installed blackout curtains in the CINP residences to curtail light emission; this issue was identified as an impact due to chick disorientation as they leave the nest site to join parents at sea (Roth et al. 1999, ALH pers. obs.).

Breeding phenology. SCMU clutch completion (i.e., date second egg is laid) typically occurs approximately 8 days after the first egg is laid (range 5-12 days; Murray et al. 1983). We therefore reported nest initiation as the date the first egg of the clutch was laid. 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, Whitworth et al. 2009b, Harvey and Barnes 2009). For example, for those nests where lay date was calculated based on observed hatch date, we subtracted 43 days and 35 days from observed hatch date for first and second eggs, respectively. Data were analyzed separately for sites with multiple clutches. Error rates were calculated at the median interval between observations; phenology data were binned into 10-day blocks to determine trends.

Productivity and nest success. We assumed that SCMU are able to lay a maximum of two eggs per clutch; separate clutches (also "attempts") within a discrete nest site were identified, in part, based on the lack of evidence to the contrary. In the event that a clutch was comprised of only one egg, we assumed that egg-laying represented a separate clutch if it occurred after published periods of egg neglect had elapsed (see Murray et al. 1983). We reported two measures of reproductive success: (1) "egg productivity" as number of eggs hatched per total number of eggs laid (comparable to long-term NPS "productivity" metric for the SBI colony), and (2) "clutch success" as those clutches where at least one egg ultimately hatched (comparable to the "hatching success" metric used for the Anacapa colony by Whitworth et al. (2005, 2008, 2011). Eggs and clutches with unknown fates were excluded from calculations.

Egg fates. Egg fates for each clutch were categorized as hatched or failed; causes of failed eggs were classified as: depredated (presumably by mice), broken, disappeared, abandoned, addled, rolled out, usurped (i.e., evidence of second pair concurrent with failure of first pair), or fate unknown. Hatching was confirmed by either the presence of chicks, hatched eggshell fragments (indicated by paper-like, detached membranes following incubation period), or by a sufficient incubation period (>35 days) followed by egg disappearance without evidence of chick mortality. Depredation rates were calculated as the percentage of eggs laid that were apparently eaten by mice prior to hatching (identified by an insufficient incubation period coupled with characteristic shiny, intact membrane and small tooth marks on the broken eggshells; see Schwemm and Martin 2005, Carter et al. 2005). Eggs with unknown fates were excluded from analysis; clutches where egg-laying order was unknown were excluded from calculations of depredation for first *versus* second eggs.

Survey Effort: Cat Canyon. In 2008-09, we monitored all accessible sites, including potential sites found in pre-breeding season searches. Search area was identical to 2007 monitoring at 1.51 acres each year (Figure 1). Surveys were conducted at approximately 5 and 10 day intervals in both years. In 2008, we conducted 15 surveys between 6 March and 17 June, with a follow-up survey on 28 July to determine if any late nesting had occurred (Appendix I). In the longer 2009 nesting season, we conducted twenty-one nest checks between 5 March and 23 July 2009 (Appendix I). We checked all previously tagged accessible sites in both years as well as all potential nesting habitat in the plot area. In 2008, 58 of 145 tagged sites were classified as "historic" (see Harvey and Barnes 2009 for discussion); in 2009, 56 of the 142 monitored sites were part of the historic category. We reported nest occupancy separately for the historic sites, as in previous years (Roth et al. 1999, Schwemm and Martin 2005, Harvey and Barnes 2009).

Survey Effort: Northeastern Areas. In 2008-09, we monitored the Northeastern Areas approximately weekly, and at least once every two weeks. Survey effort was slightly lower in 2008 than in 2009 due to limited staff availability that year. In 2008, we completed 14, 12, and 13 surveys at the Dock, House, and Landing Cove areas, respectively, between 3 March and 15 July, and conducted follow-up surveys on 28 July to determine if any late nesting had occurred (Appendix I). In 2009, as the result of a very prolonged breeding season, we ultimately completed 28, 28, and 14 surveys at the Dock, House, and Landing Cove areas, respectively, between 4 March and 11 August. The Nature Trail plot was not accessible during either breeding season due to the close proximity of nesting Brown Pelicans (*Pelecanus occidentalis californicus*; see Harvey and Barnes 2009 for discussion). In 2009, we increased the number of nest boxes in the Dock area to 18 and the House area to 16. Survey areas in the Dock and House plots were identical in both years. The Landing Cove plot was expanded from 0.60 acres in 2008 to 1.3 acres in 2009 as a result of: (1) increased staff availability and (2) decreased pelican nesting, which allowed us to access a larger area (Figure 1). House and Dock areas were analyzed separately due to larger potential for anthropogenic impacts in those areas (see Roth et al. 1999 and this paper for discussion).

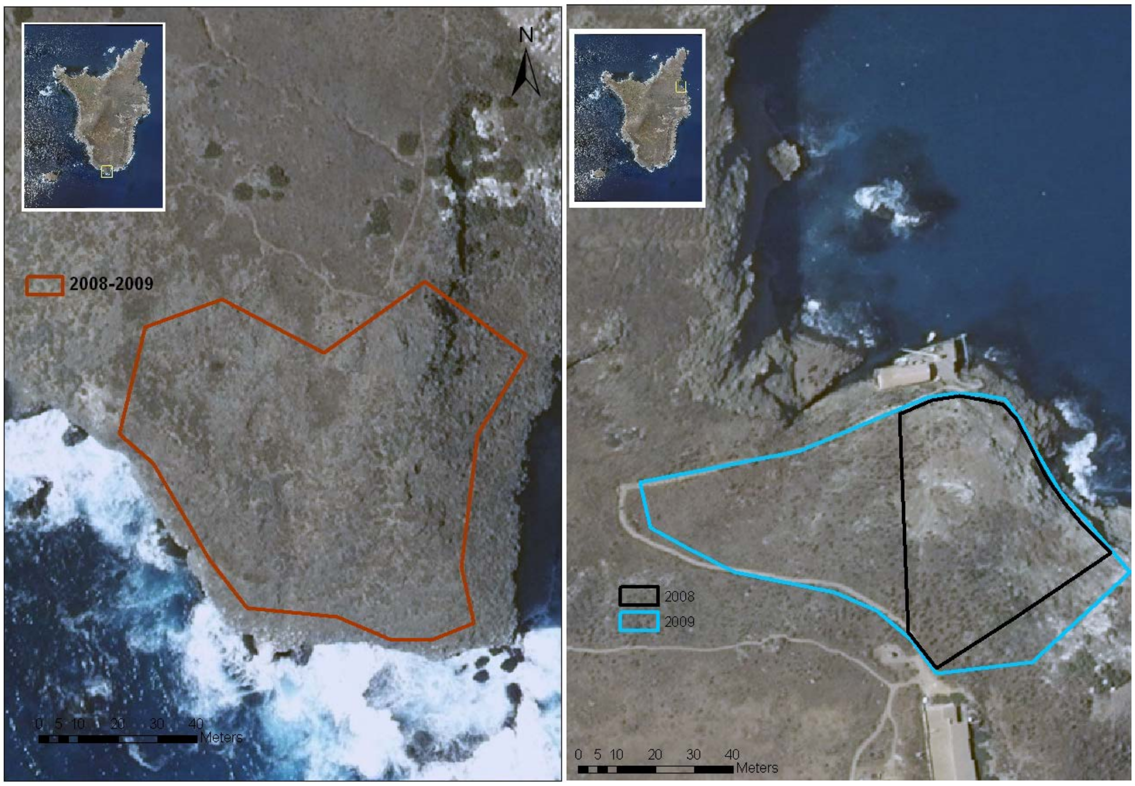

Figure 1. The Scripps's Murrelet Cat Canyon (left) and Landing Cove (right) monitoring plot survey areas in 2008-2009.

RESULTS

2008 Phenology. The 2008 nesting season at Cat Canyon began in early March (n=34 attempts initiated) and lasted about three months (Figure 2). Peak nest initiation occurred in late April, and the last clutches of the season were initiated in late May. First hatching occurred in mid-April, with peak hatching in mid-May. Phenology in the Northeastern areas (Dock, House, and LACO combined) was less protracted than observed in Cat Canyon: peak clutch initiation occurred in late March (n=14 attempts; Figure 3). The first eggs hatched in mid-May, peak hatching occurred in mid-May, and the last eggs hatched by early June.

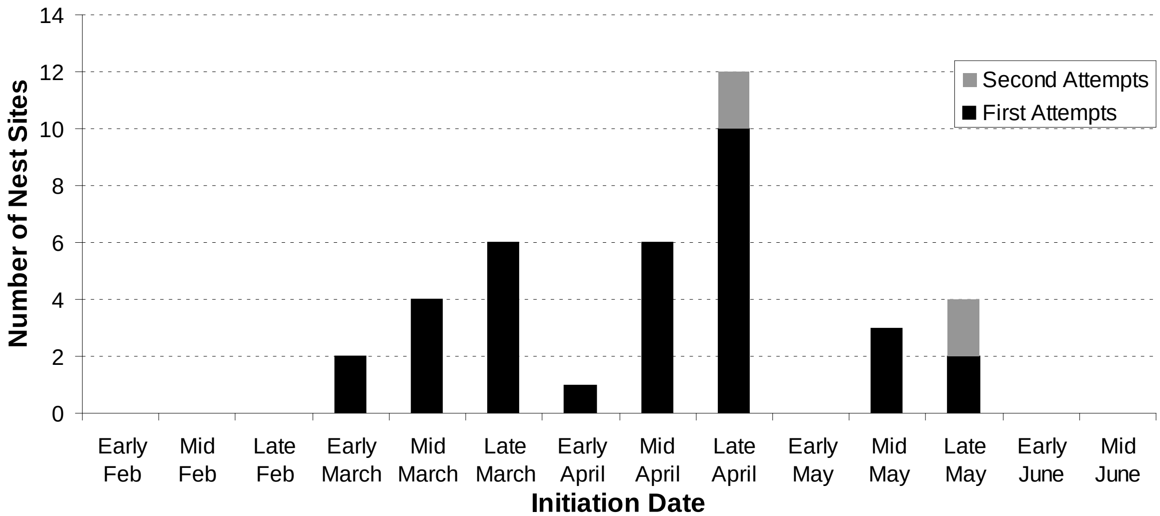

Figure 2. Scripps's Murrelet nest initiation dates at Cat Canyon in 2008.

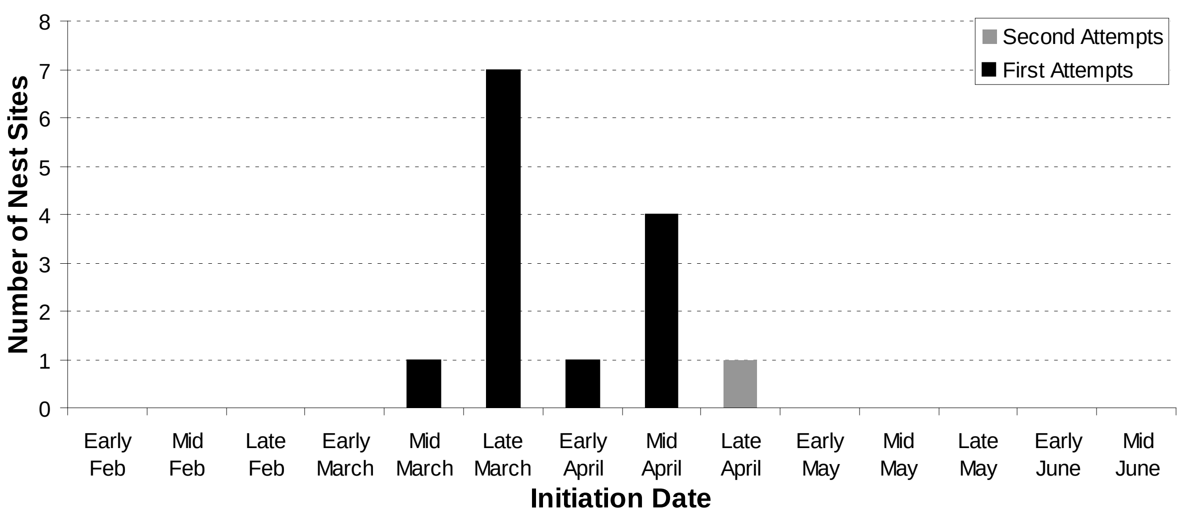

Figure 3. Scripps's Murrelet nest initiation dates in the Northeastern areas in 2008.

2008 Reproductive Performance.

Cat Canyon. We monitored a total of 40 active nests in the Cat Canyon study plot in 2008. Nest occupancy at Cat Canyon in 2008 was 50% (n=58 monitored historic sites). We observed four additional attempts in these sites, bringing the percentage of multiple attempts per active nest to 10% (44 total clutches). The 2008 egg depredation rate at Cat Canyon was 57% (n=60 eggs; Table 1). An estimated 70% of first eggs (n=37) and 35% of second eggs (n=23) were depredated. Overall egg productivity was 0.40 eggs hatched per eggs laid. Overall clutch success was 53% (n=38 clutches) at Cat Canyon in 2008. We recorded zero adult murrelet mortality in Cat Canyon in 2008.

Northeastern monitoring sites. We monitored 20 active sites in the Northeastern plots in 2008: seven in the Dock area, eight in LACO, and five in the vicinity of the CINP housing area (Table 1). Combined clutch success from Dock, House, and LACO plots was 80% (n=18). Two nest boxes (B9 and B14) were occupied at the Dock; both were successful with a total of three eggs hatched from these two nest boxes. Of eggs with known fates (n=29), 20 hatched and 9 failed to hatch following abandonment or egg breakage. No eggs in the Northeastern sites failed due to mouse depredation. We recorded zero adult murrelet mortality in the Northeastern plots in 2008.

Table 1. Nest occupancy and hatching success at Santa Barbara Island in 2008.

	Dock	Landing	House	Cat Canyon	
Nesting Activity	**Area**	**Cove**	**Area**	***Historic***	**All sites**
Total Active Sites	7	8	5	*29 (58)*	40
Total Clutches	7	9	5	*32*	44
2008 Clutch Success[1] (n)	86% (7)	86% (7)	100% (4)	*50% (28)*	53% (38)
Egg Productivity[2] (n)	64% (11)	62% (13)	100% (5)	-	40% (60)
Egg Depredation Rate[3] (n)	0% (11)	0% (13)	0% (5)	-	57% (60)

[1] Clutch Success as percentage of clutches that hatch at least one chick.
[2] Egg Productivity as number of eggs hatched per egg laid.
[3] Depredation Rate as number of eggs depredated per eggs laid.

2009 Phenology. In 2009, 27 historic sites and 13 non-historic sites were active in the Cat Canyon study area. The nesting season lasted nearly six months from earliest initiation to latest hatching. The earliest eggs of the season were laid in early February, with peaks of egg-laying in early March, late March, and mid April (n=48 first eggs; Figure 4). The last clutches of the season were initiated in mid June. First hatching occurred in late March, with peak hatching in late May; the last eggs of the season hatched in late July.

Nesting began slightly later in the Northeastern areas in 2009 than in Cat Canyon, with first initiations occurring in late February (Figure 5). The earliest eggs were observed in late February, and most attempts were initiated between early March and late April. Peak hatching occurred in early May; the last eggs of the season were laid in late June, and latest hatching occurred in mid July.

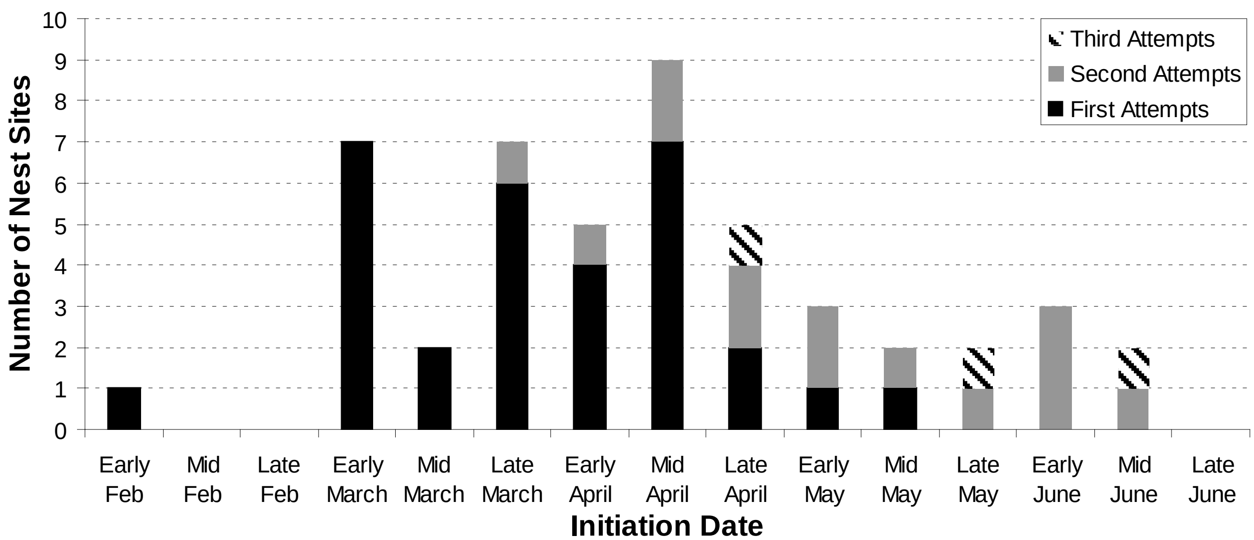

Figure 4. Scripps's Murrelet nest initiation dates at Cat Canyon in 2009.

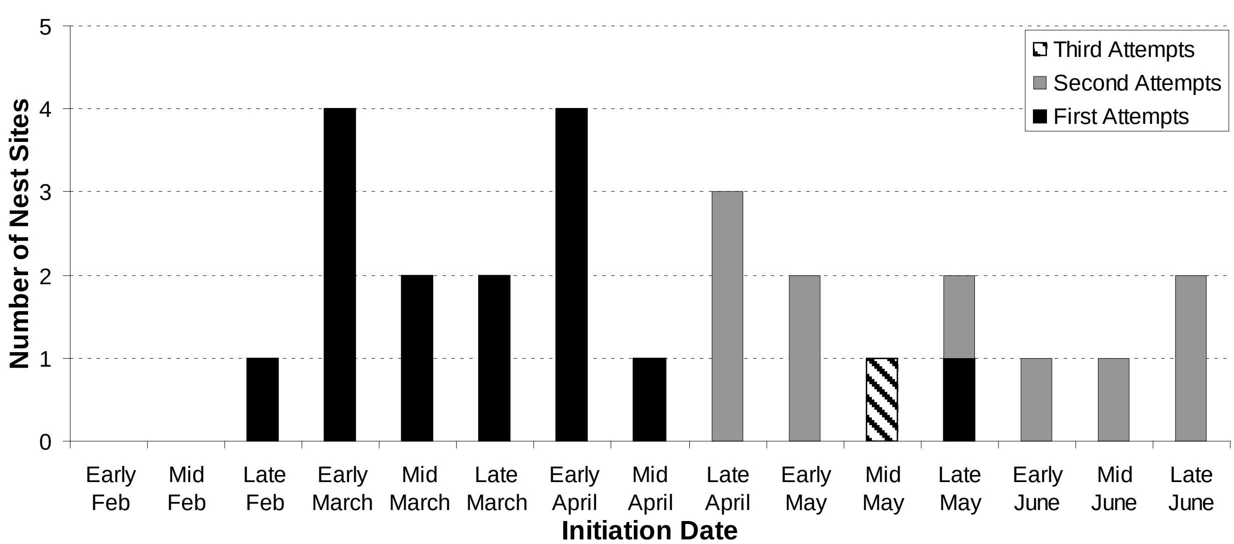

Figure 5. Scripps's Murrelet nest initiation dates in the Northeastern areas in 2009.

2009 Reproductive Performance.

Cat Canyon. Nest occupancy in Cat Canyon historic sites in 2009 was 48% (n=56 monitored sites), or 27 active nests (Table 2). We observed 18 additional clutches in these 27 sites, including three sites with three clutches each, bringing the percentage of multiple clutches laid per active nest to a very high 67%. Overall percentage of multiple clutches per site (including non-historic sites) was 55% (62 clutches in 40 active sites).

2009 clutch success in historic sites was an extremely low 25% (n=44 clutches). Clutch success from the additional 13 non-historic sites was 47% (n=19 clutches), bringing overall plot clutch success to 32% (n=62 clutches). The 2009 egg depredation rate at Cat Canyon was extremely high at 77% (n=104 eggs with known fates; Table 2). Notably, 96% of first eggs (n=50) and 59% of second eggs (n=37) were depredated. Consequently, overall egg productivity was very low at 0.20 eggs hatched per eggs laid.

Northeastern monitoring sites. We monitored a total of 49 clutches laid in 35 active sites in the Northeastern areas in 2009 (Table 2). Three of the 18 nest boxes (B14, B15, and B25) as well as one site underneath a nest box (B11) were occupied at the Dock; of these, only B25 was successful, with two sequential successful attempts. The site under B11 was abandoned, probably due to a hydraulic leak that seeped from the crane housing into this nest site. This habitat was removed to prevent reoccupation during cleanup and maintenance of the affected area.

As observed in Cat Canyon, multiple clutches were laid in a large proportion of nest sites in this monitoring complex. Of the three monitoring plots, egg productivity was the lowest at the Dock with corresponding relatively high depredation rate. In contrast, depredation was not observed in either the LACO or in the House plots. Combined productivity for these areas was moderate at 0.60 eggs hatched per eggs laid. However, the majority of clutches resulted in at least one chick during the season; consequently, ultimate clutch success was high at the House and LACO plots (90% and 75%, respectively) and low at the Dock (38%) for an overall clutch success of 61% in 2009.

We encountered eight adult murrelet carcasses in monitoring plots in 2009: three each in the House and Dock plots and one each in Landing Cove and Cat Canyon plots. Cause of mortality was attributed to avian predation for six of the eight murrelets; the remaining two carcasses appeared to be due to anthropogenic factors (both at the Dock: one entangled in fishing line and one saturated with hydraulic oil from a leak in the crane hoses). Adult mortality documented outside regular monitoring plots is reported in Whitworth et al. (2011), Thomsen and Harvey (2012), and Thomsen et al. (in prep).

Table 2. Nest occupancy and hatching success at Santa Barbara Island in 2009.

	Dock	Landing	House	Cat Canyon	
Nesting Activity	**Area**	**Cove**	**Area**	***Historic***	**All sites**
Total Active Sites	11	17	7	*27 (56)*	40
Total Clutches	18	20	11	*44*	62
2009 Clutch Success[1] (n)	38% (16)	75% (20)	90% (10)	*25% (44)*	32% (62)
Egg Productivity (n)	34% (29)	76% (34)	73% (15)	-	20% (104)
Egg Depredation Rate[3] (n)	45% (29)	0% (34)	0% (15)	-	77% (104)

[1] Clutch Success as percentage of clutches that hatch at least one chick.
[2] Egg Productivity as number of eggs hatched per egg laid.
[3] Depredation Rate as number of eggs depredated per eggs laid.

DISCUSSION

The Santa Barbara Island alcid habitat restoration project commenced in 2007 and is projected to continue through at least 2017. The success of this project will be measured first by the successful establishment of high-quality native shrub nesting habitat and, ultimately, by the degree to which newly restored native plant habitat is utilized by alcids (MSRP 2005, Harvey and Barnes 2009, Whitworth et al. 2009a, 2011). Successful establishment of suitable native plant habitat depends on many factors including rainfall, growth rate, and ability of native plants to recruit into restored habitat. On SBI, we expect that establishing sufficient shrub cover to provide new nesting habitat for SCMU will take, at minimum, 5-10 years. Colony expansion into new habitat will certainly depend on many factors in addition to habitat quality, including social cues, competition, and predation pressure. However, the rate and extent of colonization will also be limited by the number of breeding adults recruiting to the existing SBI colony. Therefore, annual baseline monitoring to assess reproductive status as well as population trends throughout the restoration timeframe is an essential component of this project. We report here nest monitoring results from the 2008-09 Scripps's Murrelet breeding seasons; results of Cassin's Auklet monitoring in 2008-2009 as well as at-sea studies of both species in 2009 are reported in Whitworth et al. (2009a, 2011).

During the project's pilot year in 2007, we identified that the land-based nest monitoring component should provide data that were comparable to (a) historic data collected since the 1980s on SBI and (b) monitoring results reported for other colonies. Since SCMU chicks depart the nest approximately two days after hatching, it is not possible to calculate a true fledging statistic. Thus the baseline nest monitoring initiated in 2007 at SBI was designed to replicate, to the greatest extent possible, the long-term monitoring program conducted there by CINP and others (Harvey and Barnes 2009). To this end, we reported the nest occupancy rate from historic sites in the long-term Cat Canyon plot, as well as one measure of reproductive success traditionally used at SBI: egg productivity, measured simply as the number of eggs hatched per number laid. Additionally, in 2007 we identified the need to have a productivity statistic that was comparable to that reported for other colonies such as Anacapa Island (Whitworth et al. 2008), Islas Coronado (Carter et al. 2006), and San Benitos (Wolf et al. 2005). To satisfy the latter requirement, we calculated "clutch success", which is analogous to the "hatching success" statistic defined in those studies as the proportion of clutches that hatch *at least* one chick.

Clutch success represents a less precise but more reliably obtained measure of reproduction than egg productivity (see Harvey and Barnes 2009, Whitworth et al. 2012). Importantly, the clutch success statistic may not directly measure the ultimate reproductive success of *pairs.* Information regarding the ability of SCMU to lay replacement clutches is limited to one record of a color-marked pair on SBI, which was cited in Murray et al. (1983). Contemporary nest monitoring does not include examination of individual adults in the nest because murrelets may abandon the nest if handled (Murray et al. 1983). Without handling individually marked birds, we were unable to determine the proportion of multiple clutches per nest site laid by one *versus* more than one pair. In either case, we consider the clutch success statistic to be a conservative estimate of colony production. On SBI, combined clutch success for the Northeastern monitoring areas was 80% in 2008 and 61% in 2009, but reached a low of 32% in the Cat Canyon plot during the 2009 breeding season. As a comparison, clutch success at the Anacapa colony averaged 30% prior to Black Rat (*Rattus rattus*) eradication and 85% thereafter (Whitworth et al. 2012).

Egg productivity rates and the closely related egg depredation statistic showed patterns similar to previous work on SBI (Murray et al. 1983, Roth et al. 1999, Schwemm and Martin 2005, Harvey and Barnes 2009). Most egg failures were attributed to mouse depredation, which occurred much more frequently at the primarily rocky Cat Canyon plot than in native shrub habitat. Since causality for early egg failures cannot always be directly measured, egg depredation may either be a primary factor or be reflective of other processes that influence egg neglect or abandonment. For example, assigning a depredation fate to first eggs that were eaten during the normal egg neglect period is relatively straightforward if the clutch is subsequently completed. However, if only one egg is laid or if second eggs are also depredated, it is very difficult to assess whether depredation occurred during egg neglect or if the egg(s) were abandoned and subsequently scavenged by mice. This has important implications for accurate reporting as well as for identifying underlying drivers of reproductive success. The extent of the impact from deer mice could be overestimated under some scenarios, particularly if nest attendance patterns (e.g., egg neglect periods or abandonment events) vary as a result of conditions such as prey availability or weather; apparent depredation rates could be expected to increase in such a case. Rates could also be underestimated if, for example, clutch completion cannot be confirmed or if eggs disappear before a fate can be assigned, as occurs regularly on SBI.

Some degree of uncertainty is therefore to be expected when examining egg depredation rates. Egg failures attributed to native deer mouse depredation on SBI have been well described in the literature, but there is not a clear consensus on the degree to which egg depredation affects overall colony productivity. Prior documentation of egg depredation is limited to periods when eggs are left unattended (Murray et al. 1983, Whitworth et al. 2009b); like previous researchers, we have found no evidence to suggest that mice are able to take eggs while the adult is in the nest. Mouse depredation has been variously reported as follows: “deer mice preyed heavily on unattended eggs” (Murray et al. 1983); “…considered the greatest threat to nest success” (Millus et al. 2007); “the level of [mouse] predation appears too high to support the murrelet population on SBI” (Sydeman et al. 1998 *in* Burkett et al. 2003). Conversely, Schwemm et al (2005) found no relationship between mouse population density and depredation rates (in a 1993-2002 time series), and concluded that “Nest predation by native mice should not be considered a cause of declines in murrelets across their range”. However, the data for mouse densities on SBI utilized in that study were collected in interior habitats where murrelet nesting does not occur; given large differences in habitat and vegetation structure, it is unlikely that such data can be reliably extrapolated to edge habitats currently used by murrelets.

In conclusion, nest occupancy from the Cat Canyon plot remained relatively stable at 48% in 2008 and 50% in 2009, but these data should be interpreted cautiously as they are not likely to be a suitable indicator of changes in colony size (see Harvey and Barnes 2009, Whitworth et al. 2011 for discussion). Spotlight surveys have the potential to yield more reliable estimates of population trends and were initiated as part of the baseline monitoring project component in 2009 (Whitworth et al. 2011).

Using conservative values, clutch success was markedly higher from nest sites located in native shrubs than at Cat Canyon in both years. Future studies to determine rates of replacement clutches should be developed to help assess the accuracy of this statistic as it relates to unique pair success. The overall egg depredation rate in Cat Canyon increased by 20% from 2008 to 2009; in total, 96% of first eggs laid there in 2009 failed due to mouse depredation. We therefore believe that mice continue to exhibit a large negative effect on this SCMU colony at certain locations, and that this may be particularly apparent in years when other factors contribute to increased egg neglect periods.

Assuming that egg depredation was the main cause of diminished clutch success, these results suggest that egg predation pressure in certain areas on SBI may approach that experienced by the Anacapa murrelet colony during rat presence there.

We recommend that mouse depredation data, particularly from the Cat Canyon study area, be further explored to assess whether they are reflective of larger scale processes such as prey availability, adult mortality during the breeding season (primarily due to Barn Owls (*Tyto alba*); see Thomsen and Harvey 2012), density dependent responses, or other factors. More work also is needed to increase sample sizes to examine nest success in native shrub habitat as well as to assess the proportion of the murrelet colony that nests in areas where high egg depredation rates occur. Of particular note, the Landing Cove plot, comprised primarily of shrub habitat, showed high success in both years of this study. Although sample sizes were low in Landing Cove, these results provide additional confirmation that restoration of native shrub habitat has excellent potential for providing long-term benefits to this important murrelet colony.

ACKNOWLEDGEMENTS

We are grateful to many individuals for enthusiastic nest monitoring assistance during the 2008-2009 breeding seasons: N. Giese, C. Leon, P. Hebért, M. Hornfeck, J. Howard, L. Koczur, J. Koepke, D. Kushner, L. Morlock, and S. Thomsen. Many thanks to the CINP maintenance staff, especially K. Bullard; to S. Chaney, K. McEachern, and D. Rodriguez for botanical expertise, R. Rudolph for assistance with GIS work. Thanks for safe transportation to: CINP skippers D. Willey, D. Brooks, R. Brooks, K. Duran, J. Spille; CINMS *Shearwater* skippers T. Shinn, C. Lara; *Retriever* skipper D. Carlson; Aspen Helicopters pilots C. McLaughlin, J. McCrory, B. Hansen, and R. Throckmorton. Thoughtful comments on this report were kindly provided by K. Barnes, H. Carter, K. Faulkner, L. Henkel, A. Little, D. Richards, and D. Whitworth. This work was funded by the Montrose Settlements Trustee Council in partnership with Channel Islands National Park.

LITERATURE CITED

Burkett, E.E., N.A. Rojek, A.E. Henry, M.J. Fluharty, L. Comrack, P.R. Kelly, A.C. Mahaney, and K.M. Fien. 2003. Report to the California Fish and Game Commission: status review of Xantus's Murrelets (*Synthliboramphus hypoleucus*) in California. Unpublished report, California Department of Fish and Game, Habitat Conservation Planning Branch, Status Report 2003-01, Sacramento, California.

Carter, H.R., G.J. McChesney, D.L. Jaques, C.S. Strong, M.W. Parker, J.E. Takekawa, D.L. Jory, and D.L.Whitworth. 1992. Breeding populations of seabirds in California, 1989-1991. Unpublished draft final report, U.S. Fish and Wildlife Service, Northern Prairie Wildlife Research Center, Dixon, California.

Carter, H.R., Sealy, S.G., Burkett, E.E. and Piatt, J.F. 2005. Biology and conservation of Scripps's Murrelet: discovery, taxonomy, and distribution. Marine Ornithology 33: 81–87.

Carter, H.R., F. Gress, D.L. Whitworth, E. Palacios, J.S. Koepke, and A.L. Harvey. 2006. Seabird monitoring at the Coronado Islands, Baja California, Mexico, in 2005. Unpublished report, California Institute of Environmental Studies, Davis, California.

Fry, D. M. 1994. Injury of seabirds from DDT and PCB residues in the Southern California Bight ecosystem. Unpublished report, U.S. Fish and Wildlife Service, Sacramento, California.

Harvey, A.L. and K.W. Barnes. 2009. Alcid habitat restoration and Scripps's Murrelet nest monitoring on Santa Barbara Island, California in 2007. Unpublished report to the Montrose Settlements Trustee Council. 28 pp.

Howell, A.B. 1917. Birds of the islands off the coast of southern California. Pacific Coast Avifauna 12: 1-127.

Hunt, G. L., Jr., R. L. Pitman, and H. L. Jones. 1980. Distribution and abundance of seabirds breeding on the California Channel Islands. Pages 443-459 in Power, D.M. (ed.). The California Islands: Proceedings of a Multidisciplinary Symposium. Santa Barbara Museum of Natural History, Santa Barbara, CA.

Kiff, L. 1994. Eggshell thinning in birds of the California Channel Islands. Unpublished report, U.S. Fish and Wildlife Service, Sacramento, California.

McChesney, J.M. and B.R. Tershy. 1998. History and status of introduced mammals and impacts to breeding seabirds on the California channel and northwestern Baja California Islands. Colonial Waterbirds 21: 3.

Millus, S. A., P. Stapp, and P. Martin. 2007. Experimental control of a native predator may improve breeding success of a threatened seabird in the California Channel Islands. Biological Conservation 138(3-4): 484-492.

Montrose Settlements Restoration Program. 2005. Final restoration plan and programmatic environmental impact statement, and environmental impact report. Report of the Montrose Settlements Restoration Program, National Oceanic and Atmospheric Administration, U.S. Fish and Wildlife Service, National Park Service, California Department of Fish and Game, California Department of Parks and Recreation, and California State Lands Commission.

Murray, K.G., K. Winnett-Murray, Z.A. Eppley, G.L. Hunt, Jr., and D. B. Schwartz. 1983. Breeding biology of the Scripps's murrelet. Condor 85: 12-21.

Roth, J.E., W.J. Sydeman, and P.L. Martin. 1999. Population size, phenology, and productivity of seabirds on Santa Barbara Island, 1998. Unpublished Report, Channel Islands National Park, Technical Report CHIS-99-002.

Schwemm, C.A., J.T. Ackerman, P.L. Martin, and W. Perry. 2005. Nest occupancy and hatching success of Xantus's Murrelets (*Synthliboramphus hypoleucus*) breeding on Santa Barbara Island, California during a twenty-year period. Pages 385-394 In: D.K. Garcelon and C.A. Schwemm (Eds.). Proceedings of the sixth California Islands symposium. National Park Service Technical Publication CHIS-05-01. Institute for Wildlife Studies, Arcata, California.

Schwemm, C.A., and P.L. Martin. 2005. Response of nest success of Xantus's Murrelets (*Synthliboramphus hypoleucus*) to native predator abundance, Santa Barbara Island, California. Pages 373-384 In: D.K. Garcelon and C.A. Schwemm (Eds.). Proceedings of the sixth California Islands symposium. National Park Service Technical Publication CHIS-05-01. Institute for Wildlife Studies, Arcata, California.

Thomsen, S.K. and A.L. Harvey. 2012. Factors influencing depredation of Xantus's Murrelets by Barn Owls on Santa Barbara Island: Summary results from the 2010 field season. Unpublished report prepared for: Montrose Settlements Restoration Program. 22 pp.

Whitworth, D.L., H.R. Carter, R.J. Young, E. Creel, G.J. McChesney, and P. Martin. 2003. Population trends of Xantus's Murrelets (*Synthliboramphus hypoleucus*) at Santa Barbara Island, California, 1991-2001. Unpublished report, Humboldt State University, Department of Wildlife, Arcata, California; and California Institute of Environmental Studies, Davis, California.

Whitworth, D.L., H.R. Carter, J.S. Koepke, F. Gress, and S. Fangman. 2005. Population assessments and monitoring for Scripps's murrelets at breeding colonies in the

Southern California Bight in 2004. Unpublished report, California Institute of Environmental Studies, Davis, California.

Whitworth, D.L., H.R. Carter, J.S. Koepke and F. Gress. 2008. Nest monitoring of Xantus's Murrelets at Anacapa Island, California: 2007 annual report. Unpublished report, California Institute of Environmental Studies, Davis, California (prepared for the American Trader Trustee Council and Channel Islands National Park). 33 pp.

Whitworth, D.L., H.R. Carter, and A.L. Harvey. 2009a. Cassin's Auklets, Xantus's Murrelets and Other Crevice-Nesting Seabirds at Santa Barbara Island, California: 2008 Surveys and Historical Status. Unpublished report, California Institute of Environmental Studies, Davis, California; Carter Biological Consulting, Victoria, British Columbia, and Channel Islands National Park, Ventura, California. 49 pp.

Whitworth, D.L., H.R. Carter, A.L. Harvey and F. Gress. 2009b. Nest monitoring of Xantus's Murrelets at Anacapa Island, California: 2009 annual report. Unpublished report, California Institute of Environmental Studies, Davis, California (prepared for the American Trader Trustee Council and Channel Islands National Park). 37 pp.

Whitworth, D.L., A.L. Harvey and H.R. Carter. 2011. Cassin's Auklets, Xantus's Murrelets and Other Crevice-Nesting Seabirds at Santa Barbara Island, California: 2009-10 Surveys. Unpublished report, California Institute of Environmental Studies, Davis, California; Channel Islands National Park, Ventura, California; and Carter Biological Consulting, Victoria, British Columbia. 84 pp.

Whitworth, D.L., H.R. Carter and F. Gress. 2012. Responses by Breeding Xantus's Murrelets Eight Years after Eradication of Black Rats from Anacapa Island, California. Unpublished report, California Institute of Environmental Studies, Davis, California (prepared for the American Trader Trustee Council and Channel Islands National Park). 79 pp.

Wolf, S., C. Phillips, J.A. Zepeda-Dominguez, Y. Albores-Barajas, and P. Martin. 2005. Breeding biology of Scripps's Murrelet at the San Benito Islands, Baja California, México. Marine Ornithology 33: 123–129.

Appendix I. Survey dates for Scripps's Murrelet monitoring at Santa Barbara Island in 2008-2009. See text for details.

Date	Cat Cyn	House	Dock	Laco	Date	Cat Cyn	House	Dock	Laco
3/6/2008	x				4/8/2009		x	x	
3/7/2008		x	x	x	4/16/2009		x	x	
3/11/2008	x				4/17/2009	x			
3/19/2008		x	x	x	4/18/2009		x		
3/20/2008	x				4/20/2009				x
3/23/2008		x			4/21/2009	x			
3/24/2008			x		4/22/2009		x	x	
3/25/2008	x				4/29/2009		x	x	
4/3/2008	x				4/30/2009	x			
4/5/2008		x	x	x	5/3/2009			x	
4/7/2008	x		x		5/4/2009			x	x
4/17/2008	x				5/5/2009	x			
4/18/2008		x		x	5/6/2009		x	x	
4/21/2008		x			5/13/2009		x	x	
4/22/2008	x				5/14/2009	x			
4/23/2008		x	x	x	5/16/2009				x
4/30/2008		x	x	x	5/18/2009			x	
5/1/2008	x				5/19/2009	x			
5/5/2008		x	x	x	5/20/2009		x	x	
5/6/2008	x				5/27/2009		x	x	
5/14/2008			x		5/28/2009	x			
5/15/2008		x		x	5/31/2009				x
5/20/2008	x		x	x	6/2/2009	x			
5/28/2008	x				6/3/2009		x	x	x
5/30/2008			x		6/10/2009		x	x	
6/2/2008		x	x	x	6/11/2009	x			
6/4/2008		x	x		6/13/2009		x		
6/11/2008			x	x	6/14/2009				x
6/12/2008	x				6/15/2009	x			
6/17/2008	x			x	6/16/2009		x	x	
6/26/2008				x	6/24/2009		x	x	
3/4/2009			x	x	6/25/2009	x			
3/5/2009	x				6/29/2009				x
3/6/2009		x			6/30/2009	x			
3/8/2009		x	x		7/1/2009		x	x	
3/9/2009		x	x	x	7/8/2009		x	x	
3/10/2009	x				7/9/2009	x			
3/11/2009		x	x		7/12/2009				x
3/18/2009		x	x		7/14/2009	x			
3/19/2009	x				7/15/2009		x	x	
3/23/2009				x	7/22/2009		x	x	
3/24/2009	x				7/23/2009	x			
3/25/2009		x	x		7/25/2009				x
4/1/2009		x	x		7/28/2009	x			
4/2/2009	x		x		7/29/2009		x		
4/6/2009			x	x	8/5/2009		x		
4/7/2009	x				8/11/2009				x