

**Nest Monitoring of Xantus's Murrelets  
(*Synthliboramphus hypoleucus*)  
at Anacapa Island, California: 2005 annual report**

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## EXECUTIVE SUMMARY

- From March-August 2005, the California Institute of Environmental Studies conducted the sixth year (2000-05) of Xantus's Murrelet (*Synthliboramphus hypoleucus*) nest monitoring in sea caves and selected sample areas at Anacapa Island, California. With support from the American Trader Trustee Council and Channel Islands National Park, monitoring was initiated in 2000 to provide three years of baseline data prior to complete eradication of Black Rats (*Rattus rattus*) from the island in December 2002. In 2003-05, we have monitored the response of murrelets to the absence of rat predation for the first three years post-eradication.
- A considerable increase in murrelet nesting effort occurred in 2005 compared to previous years: 1) more active nests were recorded in the sea caves (18 nests) and over the entire island (26 nests); 2) higher nest occupancy was found in sea caves (61%) and over entire island (68%); and 3) nine new nest sites were discovered, including three new sites in the sea caves.
- Murrelets continued their colony expansion into habitats previously occupied by rats, with six new nest sites (including four sites in Landing Cove alone) established outside of the sea caves in 2005, where none were known prior to 2003.
- Murrelet hatching success in the sea caves (83%) and over the entire island (88%) was higher in 2005 than in any year since monitoring began, despite extremely late nesting phenology compared to most previous years. The mean nest initiation date in 2005 (2 May) was similar to 2004 (1 May), but was 19- 32 days later than observed in 2000-03 (30 March - 13 April).
- The number of monitored nest sites in Anacapa sea caves has increased 75% since the eradication of rats, while the number of active murrelet nests has increased 42% post-eradication (i.e., 2000-02 versus 2003-05). Hatching success in sea caves has nearly doubled post-eradication (80% in 2003-05 vs. 42% in 2000-02). Over half (52%) of all pre-eradication nests monitored were taken by rats, but no rat-depredated nests and only three (7%) mouse-depredated nests have been recorded since 2002.
- Endemic Deer Mice (*Peromyscus maniculatus anacapae*) continued to prey on murrelet eggs, as found in other years post-eradication. Small numbers of depredated eggs apparently not from monitored nests were found in sea caves, but we documented no murrelet nest failures due to mouse depredation in 2005.
- Reduced prey availability and related lower hatching success in some years (e.g., 2004) as well as anthropogenic factors unrelated to rat predation (e.g., oil spills) will slow population recovery to some degree. However, rat depredation was likely the primary factor detrimentally impacting this colony over the last century and the eradication of rats has led to improved hatching success and colony growth that should eventually result in the development of a much larger colony in the future.
- Ongoing monitoring is needed to document continued recovery of Xantus's Murrelet at Anacapa Island.

## INTRODUCTION

With funds from the *American Trader* oil spill settlement, the American Trader Trustee Council (ATTC; comprised of representatives from the California Department of Fish and Game, National Oceanic and Atmospheric Administration, and U.S. Fish and Wildlife Service), in league with Channel Islands National Park (CINP) sponsored a restoration program to enhance seabird breeding habitat on Anacapa Island, California, by eradicating non-native Black Rats (*Rattus rattus*; ATTC 2001). The Xantus's Murrelet (*Synthliboramphus hypoleucus*) was identified as the seabird species expected to benefit most from the Anacapa Island Restoration Program. The murrelet colony at Anacapa Island is thought to have been severely impacted by rats since at least the early 1900s (Hunt et al. 1979, Carter et al. 1992, McChesney and Tershy 1998, McChesney et al. 2000, Whitworth et al. 2003a) and ATTC determined that rat eradication would likely assist murrelet population recovery and prevent eventual loss of this important colony. In 2004, murrelets were listed as threatened by the California Fish and Game Commission and the expected recovery of the Anacapa murrelet colony was considered a significant step toward increasing the species' probability of maintaining viable populations in California (Burkett et al. 2003).

Island Conservation and Ecology Group and CINP successfully eliminated rats from Anacapa Island in two phases: a) East Anacapa in December, 2001; and b) Middle and West Anacapa in November, 2002. While non-native introduced predators have been eradicated from several murrelet breeding islands in Baja California and southern California over the past 30 years (Hunt et al. 1979, McChesney and Tershey 1998), little effort has been made to document the benefits of predator eradication for murrelets or other seabirds on these islands. To measure the effectiveness of rat eradication for the murrelet population at Anacapa Island, ATTC sponsored an experienced team of biologists from Humboldt State University, California Institute of Environmental Studies (CIES), Channel Islands National Marine Sanctuary (CINMS), and Hamer Environmental to design and implement a Xantus's Murrelet Monitoring Program. The two primary goals of the monitoring program are: a) to determine baseline levels of population size indices and breeding success prior to rat eradication; and b) to measure expected increases in murrelet population size and breeding success after the removal of rats. From 2000-03, the team developed innovative population monitoring techniques (especially nocturnal spotlight surveys, ornithological radar, and sea cave nest monitoring) which have provided reliable indices of murrelet population size and breeding success for measuring changes over time (Whitworth et al. 2003a; Hamer et al. 2003a).

In 2004, budgetary constraints compelled ATTC to reduce funding for the Xantus's Murrelet population monitoring program. CIES was funded to continue nest searches and monitoring in sample areas (i.e., sea caves and other coastal areas) at Anacapa Island. Nest searches and monitoring alone provide standardized data in these sample areas: a) to measure nesting effort, hatching success, and nest depredation rates; and b) to detect expansion of the colony into habitats previously occupied by rats. While sample areas may not be representative of all areas of the island, this reduced monitoring program allows for continued annual information for measuring the general progress of recovery. Additional efforts (i.e., spotlight surveys, radar surveys, and broad-scale nest searches) will be necessary in the future to better measure how overall population size and distribution have changed over time.

In 2005, with joint funding from ATTC and CINP, CIES has continued murrelet nest monitoring in sea caves and expanded nest searches in cliff, shoreline and offshore rock habitats around Anacapa Island. Our efforts in 2005 marked the sixth consecutive year of Xantus's Murrelet nest monitoring and the third year of monitoring since the successful eradication of Black Rats from Anacapa. In this report, we present the results of 2005 nest monitoring and compare these results with data from previous years.

## METHODS

### Study Area

Anacapa Island is the easternmost and smallest of the northern four California Channel Islands and sits just off the California mainland, 15 km southwest of Ventura (Fig. 1). It is comprised of three small islets (West, Middle, and East; Fig. 2) separated by narrow channels which are sometimes exposed at low tide. The narrow island chain is approximately 7.5 km long and is surrounded by 17.5 km of steep, rocky cliffs punctuated with over 100 sea caves (Bunnell 1993). West Anacapa is the largest (1.7 km<sup>2</sup>) and highest (284 m) of the three islets, followed by Middle Anacapa (0.6 km<sup>2</sup>, 99 m), and East Anacapa (0.5 km<sup>2</sup>, 73 m). Anacapa Island is managed by CINP which maintains quarters for staff and facilities for campers, but the island is otherwise uninhabited. Surrounding waters out to 9.7 km (6 miles) are managed by CINMS, out to 4.8 km (3 miles) by California Department of Fish and Game, and out to 1.6 km (1 mile) by CINP.

### Field Logistics

We used the CINMS research vessel *Shearwater* for transportation to and from Anacapa Island and accommodations while at the island. All field work was conducted by DLW, JSK, and volunteers from CINMS and the Channel Islands Naturalist Corps. Access to sea caves and other sample areas was performed in a 3.8 m Zodiac<sup>®</sup> inflatable craft powered by 15-25 hp outboard engines provided by ATTC through the CINP and CINMS. We used the CINMS vessel *Xantu* for transportation and support during a single-day trip for the final nest check on 20 August. Boats and personnel were supplied with all required safety equipment.

### Nest Monitoring

In March-August 2005, we conducted nest searches and monitoring in the ten sea caves monitored in 2000-04 (Whitworth et al. 2002a,b, 2003a, 2004a,b; Fig. 2). Caves were named after Bunnell (1993). All potential nesting habitat in the sea caves was searched using hand-held flashlights during each visit. Sea caves were checked once every two weeks in 2005, whereas they were checked weekly in most previous years. Taking into account the possibility of late nesting and the need to extend monitoring beyond June (as occurred in 2004), we considered biweekly checks to be the most efficient survey schedule with available time, funds, and boat support. While this change in frequency of nest checks resulted in less exact data for measuring breeding phenology, we considered that it did not change the accuracy of measuring hatching success. Only sites which were active during the penultimate nest check were inspected during the last visit to the island on 20 August.

Systematic efforts to examine potential murrelet nesting areas in cliff, shoreline and offshore

rock habitats began in 2003 and were continued and expanded in 2004-05 (Fig. 2). We used methods similar to sea cave nest monitoring to thoroughly search: 1) cliffs in Landing Cove on East Anacapa (2003-05); 2) an offshore rock and rocky peninsula (Cat Rock and Rat Rock, respectively) off West Anacapa (2003-05); 3) shoreline areas on the south side of Middle Anacapa near East Fish Camp (2004-05); and 4) Rockfall Cove on the south side of Middle Anacapa (2005). Previously tagged sites in these sample areas were checked biweekly as for sea cave sites, but due to the large areas to be searched, more extensive surveys of these sample areas were conducted only once or twice during the breeding season after egg laying had commenced in most in sea caves. By initiating limited monitoring outside of sea caves, we aimed to detect when murrelets begin colonizing nesting areas that previously could not be used due to the presence of rats.

Monitored nest sites were identified as suitable crevices or sheltered sites, containing an incubating or brooding adult or other evidence of past or present murrelet breeding (i.e., whole unattended eggs, broken or hatched eggshell fragments, or eggshell membranes). During the first visit of the year, we carefully inspected each cave and collected any remaining eggshell fragments from the past breeding season to avoid confusion with previous nesting efforts. During subsequent biweekly visits to the sea caves, we recorded the contents of each tagged nest (e.g., empty nest, one or two unattended eggs, incubating or brooding adult, abandoned eggs, broken or hatched eggshell fragments) and we searched for other new nest sites that had not been present in previous years. Incubating adults were observed briefly with a small flashlight but were not handled or prodded to reduce the possibility of nest abandonment due to researcher disturbance.

Nesting Phenology - Nesting phenology was determined from nest monitoring and observations of chicks accompanied by adults at sea as they departed the island. A range of possible clutch initiation dates (laying date of the first egg) was estimated for each nest or at-sea chick observation by subtracting an estimated period of time from the date of reliable evidence of laying or hatching of the first egg of the clutch, such as: 1) one unattended egg prior to the laying of the second egg (i.e., between 1-7 days since laying); 2) “chicks in nest” (i.e., between 0-3 days since hatching); 3) “fresh hatched eggshell fragments” (i.e., 3-7 days since hatching); or 4) the first date in a series of repeated checks with incubating birds (i.e., 1-14 days since laying). The number of days subtracted took into account: a) the mean time between the laying of two eggs in a clutch is 8 days; b) the mean time between clutch completion and the start of incubation is 2 days; c) the mean incubation period is 34 days (range = 27- 44 days); and d) the mean time from hatching to nest departure is 2 days (Murray et al. 1983). By placing mean nest initiation dates in 10-day blocks each year, we partly accounted for error in the estimation of mean initiation date for each nest. However, with biweekly nest checks in 2005, greater error was involved in this process than with weekly nest checks in 2000-04.

Hatching Success - Hatching success was determined as the percent of monitored nest sites where a “nesting attempt” occurred (i.e., a clutch of 1-2 eggs was laid) that successfully hatched at least one egg. Nesting attempts were considered to have successfully hatched only if chicks were seen or freshly hatched eggshell fragments (identified by the dried or bloody membrane which separates from the shell) were found at the nest site. Failed nesting attempts were classified as either depredated or abandoned. Depredated nests were usually identified by the presence of broken eggshells in or near the site, but we included a few attempts where eggs disappeared (presumably removed by rats or mice) before possible

hatching. Broken eggs were examined for signs of depredation by rats (larger bite marks on shell edges or greater crushing of eggshells) or mice (smaller bite marks on shell edges with little or no crushing). Nesting attempts were considered abandoned when whole unattended eggs were observed over two consecutive nest checks.

Nest Occupancy – In 2005, we determined annual nest occupancy in sea caves as the percentage of the total monitored nest sites found over the course of the study (regardless of when the site was first tagged) in which at least one egg was laid that year. This technique differed from that used in previous years but increased the comparability of occupancy rates between years. Potential nest sites were not tagged until some evidence of nesting was observed, but because all habitat in sea caves was thoroughly searched, we believe that untagged sites in the caves could reliably be presumed to have been unoccupied in the years prior to when the first evidence of nesting was observed. Using this method, calculated occupancy rates in sea caves for a particular year will decrease as the murrelet population increases and new monitored sites are added, but occupancy rates will more reliably reflect growth of the murrelet population. Estimates of nest occupancy over the entire island were calculated as for the sea caves, but because systematic nest searches in sampled areas began in different years (*see above*), the total number of monitored sites used to calculate occupancy differed among years.

## RESULTS

### NEST MONITORING IN 2005

Nesting Effort and Occupancy - In March-August 2005, we monitored a total of 37 Xantus's Murrelet nest sites, including 28 sites in ten sea caves and nine sites in cliff, shoreline, and offshore rock habitats (Table 1). We discovered a total of 26 active murrelet nests in 25 occupied sites (two separate nesting efforts were observed in one monitored site in Respiring Chimney Cave), including 18 nest attempts in sea caves and eight nest attempts in other sampled habitats (Table 1). Nesting was observed in nine of the ten (90%) monitored sea caves, and all but one of the cliff/shoreline/offshore rock plots, including five nests in the cliffs at Landing Cove on East Anacapa, two nests along the shoreline in Rockfall Cove on Middle Anacapa, and a single nest on Cat Rock off West Anacapa. The lone monitored site along the East Fish Camp shoreline on Middle Anacapa was destroyed by a landslide during winter storms and excluded from analyses. A total of nine new sites were established over the entire island in 2005, including three new sites in the sea caves. Total occupancy over the entire island was 68% (25 occupied sites/37 monitored sites), 61% (17 occupied/28 monitored sites) in the sea caves, and 89% (8 occupied/9 monitored sites) in cliff/shoreline/offshore rock habitats (Table 1).

Nesting Success - Overall hatching success of Xantus's Murrelets was 88% (23 hatched/26 nests) of active sites (Table 1), the highest success observed over the past six years (Table 2). Hatching success was 83% (15 hatched/18 nests) in the sea caves and 100% (8 hatched/8 nests) in the cliff/shoreline/offshore rock habitats. We treated two nests observed in one monitored site as separate nesting efforts by different murrelet pairs. The first nesting effort successfully hatched two eggs, but only one chick apparently departed from the nest and the other chick was found dead outside the nest crevice. The first egg of the second nesting effort was observed 12 days after finding the hatched egg shells and dead chick from the first

nesting effort, although hatching may have occurred several days earlier. Sufficient time was available for the laying of a replacement clutch in the same site, if the missing chick also died at fledging. However, sufficient time also was available for egg production by a second pair of murrelets after the site was vacated by the first pair and the dead chick may have been moved out of the site by the second pair. Sufficient time was not available for a second clutch by one pair of birds (i.e., laying of another clutch after successfully rearing chicks from the first clutch) because of the time required to raise the chick at sea.

Only three nest failures were recorded in the sea caves in 2005, all due to abandonment (one each in Pinnacle, Lava Bench #1, and Respiring Chimney caves). The abandoned egg in Lava Bench Cave #1 was found in an open site on the cave floor, but near a small marginal crevice site. To our knowledge, this egg was never incubated, but we included this “site” in our monitoring data even though it may not have been an actual nest. We did not cause any incubating adults at the other two nests to flush or move off eggs during nest monitoring and do not believe that abandonment of these three sites was related to monitoring disturbance.

Although we did not document depredated eggs in any active monitored sites in 2005, three mouse-depredated eggs were found, one each in Lonely at the Top, Aerie, and Pinnacle caves. The depredated egg in Lonely at the Top Cave likely came from an undetected nest in deep crevices in the back of the cave. Depredated eggs from monitored and unmonitored sites have been found in this cave in previous years (Appendix 1). We suspect the depredated egg in Aerie Cave may have originated from nest #3, a monitored site where nest contents are difficult to observe. The depredated eggshell fragments were found down slope from this site, although the site also hatched at least one egg. The depredated egg in Pinnacle Cave was an abandoned egg from a late nesting effort in 2004. We found an abandoned whole egg in this site during our first nest check in 2005, but the egg was depredated before it was to be collected on a subsequent nest check.

Timing of Breeding - Murrelet nests (including a possible replacement clutch) were initiated between 11 April and 2 June, with a mean nest initiation date of 2 May ( $\pm 14$  d). We noted several peaks in the number of nests initiated during each 10-11 day period, with strong peaks in mid-April and early May and a weaker peak in late May (Fig. 3). Successful nests hatched over 52 days between 25 May and 16 July, with a mean hatch date of 12 June ( $\pm 14$  d).

Other Species - Both Cassin's Auklet (*Ptychoramphus aleuticus*) nests discovered on Rat Rock (West Anacapa) in 2003 were active in 2005, although nesting Brandt's Cormorant (*Phalacrocorax penicillatus*) above the auklet nest crevices prevented systematic monitoring and determination of breeding success in these sites. We documented four Pigeon Guillemot (*Cepphus columba*) nests in the sea caves: a) one nest in a former murrelet site in Aerie Cave; and b) three nests in Keyhole Cave, including a guillemot nest in the former murrelet site which was usurped by guillemots in 2003. One Black Oystercatcher (*Haemotopus bachmani*) nest was also discovered in Lava Bench Cave #1 and successfully hatched.

## **PRE-ERADICATION VERSUS POST-ERADICATION**

Nest Monitoring in Sea Caves - The total number of monitored sites in sea caves increased each year from 13 sites in 2000 to 28 sites in 2005 (Table 2, Fig. 4), with the largest increase (+8 sites) occurring in 2003, the first murrelet breeding season after the removal of rats. The number of monitored sites has increased 75% in the three years since 2002.

A total of 75 nests (including two possible replacement clutches) were initiated in sea caves from 2000-05, with general increases each year except 2004, when murrelet breeding effort was delayed and much reduced (Table 2, Fig. 4). The number of sea cave nests increased 42% between pre-eradication years (31 nests in 2000-02) and post-eradication years (44 nests in 2003-05). Occupancy in sea caves has ranged from 32% in 2000 to 61% in 2005 (Table 2, Fig. 5). Occupancy was consistently low pre-eradication (32-39%), but increased markedly post-eradication (54-61%), except in 2004 (39%).

Overall hatching success in the sea caves was 64% (48 hatched/75 nests), but was much higher post-eradication (80%; 35 hatched/44 nests) than pre-eradication (42%; 13 hatched/31 nests). Post-eradication hatching success in sea caves was consistently high (73-83%; Table 2, Fig. 6), but was quite variable pre-eradication (18-78%). However, high hatching success in 2000 (78%) does not take into account depredated eggs of unknown origin (i.e., from non-monitored sites) found in several caves that year (Appendix 1).

The overall nest failure rate in sea caves was 36%, with 19 depredated nests (25%) and 8 abandoned nests (11%). The nest depredation rate was much lower post-eradication (7%; 3 nests) compared to pre-eradication (52%; 16 nests; Table 2, Fig. 6). The proportion of abandoned nests was roughly similar pre- versus post-eradication (14% and 6%, respectively). Highest depredation rates of 73% and 55% were recorded pre-eradication in 2001 and 2002, respectively. No depredated nests were noted in 2005, although a missing egg in 2003 and two depredated nesting attempts in 2004 were attributed to endemic Deer Mice (*Peromyscus maniculatus anacapae*).

Colony Expansion - From 2003 to 2005, a total of 12 nesting attempts in 10 sites were discovered during nest searches in non-sea cave habitats (i.e., cliffs, shoreline, offshore rocks) post-eradication, where none were known prior to 2003 (Table 3). Occupied murrelet nest sites were first found in the Landing Cove cliffs (one site) and Cat Rock (one site) in 2003. Two more occupied nest sites were discovered in 2004, one in Landing Cove and another along the shoreline of East Fish Camp. Six new occupied nest sites were found in 2005, four in Landing Cove and two in Rockfall Cove. Nest occupancy in monitored nest sites outside sea caves was low in 2003 and 2004 (29% and 25%, respectively) but increased markedly in 2005 (89%). Nearly all (92%) nesting attempts in non-sea cave habitats successfully hatched, and none were depredated. The lone failed nesting attempt at East Fish Camp in 2004 was abandoned.

Timing of Breeding – Timing of breeding (including two possible replacement clutches) differed significantly among years (ANOVA  $F_{5,87} = 12.41$ ;  $P < 0.0001$ ), with murrelet nests initiated significantly later in 2004 and 2005 than in any of the previous four years (Tukey HSD test; all  $P < 0.03$ ). Mean nest initiation date ranged from 30 March ( $\pm 11$  d) in 2000 to 2 May ( $\pm 14$  d) in 2005 (Table 3; Fig. 3).

## DISCUSSION

Xantus's Murrelet nest monitoring at Anacapa Island in 2005 provided strong evidence of improvement in breeding conditions and colony growth since the total eradication of Black Rats from the island in the fall of 2002. Almost every index of murrelet nesting effort and



breeding success was higher in 2005, including:

- more active nests discovered in sea caves (18 nests) and over the entire island (26 nests) than in any year since monitoring began;
- higher nest occupancy in sea caves (61%) and over entire island (68%) than in any previous year;
- higher hatching success in sea caves (83%) and over the entire island (88%) than in any previous year;
- no nest failures resulting from mouse or rat-depredation; and
- a higher number of new nest sites established (9 nests) than in any year except 2003 (10 nests).

Because systematic nest searches and monitoring were mostly limited to sea caves in 2000-02, strict comparisons of nesting effort and success within the sea caves provide the most standardized evidence of changes in murrelet breeding conditions among years. However, occasional nest searches from 1991-2002 demonstrated that accessible habitats outside of sea caves, particularly the Landing Cove cliffs and Cat Rock, were virtually devoid of nesting murrelets prior to the eradication of rats (Carter et al. 1992, unpubl. data; McChesney et al 2000, Whitworth et al. 2003a). We suspect few nests were initiated in these areas prior to 2003. Comparisons over the entire island may more reliably reflect the extent of the increase in nesting success and effort since the eradication of rats. Regardless of whether comparisons are limited to sea caves or over the entire island, data clearly indicated that breeding conditions for murrelets at Anacapa Island have improved markedly since 2002. Overall nesting effort and hatching success have nearly doubled post-eradication, while depredation has been nearly eliminated as a cause of murrelet nest failure.

Increased breeding by Xantus's Murrelets in suitable but previously unoccupied nesting habitats on Anacapa Island (particularly the cliffs in Landing Cove) has been one of our most encouraging findings. The first active nests outside of sea caves were found in Landing Cove and at Cat Rock in 2003 (Whitworth et al. 2004a). The marked increase in nesting outside sea caves in 2005 likely represents a more widespread re-colonization of these habitats which should continue into the future. In addition to current monitoring, we suggest that much wider surveys of upper island and shoreline habitats of East, Middle and West Anacapa should be conducted in 2006 or future years to determine the extent to which murrelets and other seabirds are using previously unoccupied habitats. To prevent disturbance to other sensitive seabird species, surveys of upper habitats at West Anacapa will need to be conducted in the fall, after Brown Pelicans (*Pelecanus occidentalis*) and Double-crested Cormorants (*Phalacrocorax auritus*) have finished breeding (see McChesney et al. 2000).

The increased nesting effort in sea caves and expansion of the colony into new areas in 2005 were somewhat greater than we had expected. Detectable increases in the overall Anacapa murrelet population were not expected for several years, because murrelets and other alcids have relatively low reproductive rates, strong natal philopatry, and deferred sexual maturity (Murray et al. 1983; Drost and Lewis 1995; Gaston and Jones 1998). In 2005, a large group of source birds may have been derived partly from a relatively large number of murrelet chicks hatching on East Anacapa in 2002 (following earlier eradication there in fall 2001) and many surviving to breeding age (probably 3-4 years as in the congeneric Ancient Murrelet [*Synthliboramphus antiquus*; Gaston 1990]) to form a strong cohort of first-time breeders. Our monitoring efforts in 2002 were focused mainly on Middle and West Anacapa and we

would not have documented such a strong local response immediately post-eradication at East Anacapa.

In the 2003 breeding season (first year post-eradication), high nesting effort and high hatching success occurred in sea caves at Anacapa, potentially contributing to another strong cohort of first-time breeders in 2006. However, factors unrelated to rat predation could affect murrelet breeding (Whitworth et al. 2004b). Murrelets, like all seabirds, inhabit a highly variable marine environment where the interactions of diverse oceanographic, biologic and anthropogenic factors (e.g., mouse and raptor predation, prey availability, ENSO events, light pollution and potential oil spills) often result in significant year-to-year fluctuations in nesting effort and productivity (Harris and Birkhead 1985, Gaston and Jones 1998). Annual monitoring should be continued to document the annual progress of colony recovery. Without banded individuals and other data on population changes, annual data are needed for best possible measurement of population changes and best interpretation of underlying factors for changes.

Considering the increased nesting effort in sea caves and expansion of habitats used in 2003-05, statistically detectable increases in the overall population size of Xantus's Murrelets at Anacapa Island may occur sooner than anticipated. However, as observed in 2004, occasional poor reproductive seasons are to be expected on occasion and will slow the rate of population recovery. Still, over the past century rat predation was likely the primary factor detrimentally impacting the Anacapa murrelet colony (McChesney and Tershey 1998), and the eradication of rats has greatly improved future prospects for the murrelet population. The ATTC and CINP intend to provide funds to CIES for at least two more years of the Xantus's Murrelet Monitoring Program at Anacapa Island in 2006-07. While existing funds may be exhausted after 2007, continued funding may be derived from other sources. Monitoring and other studies need to continue annually after 2007 to continue to provide sufficient data to measure changes in sample areas. In addition, change in the overall population must be measured periodically with spotlight and radar surveys (Whitworth et al. 2003a; Hamer et al. 2003a).

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Table 1: Number of nests monitored and nesting success for Xantus's Murrelets at Anacapa Island in 2005.

| Sea Cave/<br>Shoreline Plot | Monitored<br>Sites | Occupied<br>Sites | Nesting<br>Attempts | Hatched<br>Nests | Predated<br>Nests | Abandoned<br>Nests |
|-----------------------------|--------------------|-------------------|---------------------|------------------|-------------------|--------------------|
| Refuge                      | 5                  | 1                 | 1                   | 1                | 0                 | 0                  |
| Lava Bench #1               | 2 <sup>1</sup>     | 2                 | 2 <sup>1</sup>      | 1                | 0                 | 1 <sup>1</sup>     |
| Lava Bench #2               | 1                  | 1                 | 1                   | 1                | 0                 | 0                  |
| Respiring Chimney           | 3                  | 2 <sup>2</sup>    | 3 <sup>2</sup>      | 2 <sup>2</sup>   | 0                 | 1                  |
| Lonely at the Top           | 2                  | 1                 | 1                   | 1                | 0                 | 0                  |
| Confusion                   | 0                  | 0                 | 0                   | 0                | 0                 | 0                  |
| Pinnacle                    | 4                  | 3                 | 3                   | 2                | 0                 | 1                  |
| Moss                        | 4                  | 4                 | 4                   | 4                | 0                 | 0                  |
| Aerie                       | 5                  | 2                 | 2                   | 2                | 0                 | 0                  |
| Keyhole                     | 2                  | 1                 | 1                   | 1                | 0                 | 0                  |
| Sea Cave Totals             | 28                 | 17 <sup>2</sup>   | 18                  | 15               | 0                 | 3                  |
| Cat Rock                    | 1                  | 1                 | 1                   | 1                | 0                 | 0                  |
| Rockfall Cove               | 2                  | 2                 | 2                   | 2                | 0                 | 0                  |
| East Fish Camp              | 0 <sup>3</sup>     | 0                 | 0                   | 0                | 0                 | 0                  |
| Landing Cove                | 6                  | 5                 | 5                   | 5                | 0                 | 0                  |
| Shoreline Plots Total       | 9                  | 8                 | 8                   | 8                | 0                 | 0                  |
| Anacapa Island Total        | 37                 | 25 <sup>2</sup>   | 26                  | 23               | 0                 | 3                  |

<sup>1</sup> One egg found in open site on cave floor was included in analysis as an active nest, although the egg was abandoned and likely never incubated. This site was not tagged and may not be an actual nest.

<sup>2</sup> Two nesting attempts occurred at one monitored site. The first nesting attempt resulted in two hatched eggs, although one chick failed to depart the nest and was found dead just outside the site. We treated the second nesting attempt as from a second pair of adults but it also may have been a replacement clutch from the first pair (see text).

<sup>3</sup> The single monitored site in this area was destroyed by a landslide during storms over the winter 2004-05.

Table 2: Breeding indices for Xantus's Murrelet nest sites in sea caves at Anacapa Island, before and after eradication of Black Rats.

| Nest Site Summary             | Pre-Eradication Year |      |                 |                | Post-Eradication Year |      |                 |                |
|-------------------------------|----------------------|------|-----------------|----------------|-----------------------|------|-----------------|----------------|
|                               | 2000                 | 2001 | 2002            | <b>2000-02</b> | 2003                  | 2004 | 2005            | <b>2003-05</b> |
| Tagged & Monitored            | 13                   | 15   | 16              | <b>16</b>      | 24                    | 25   | 28              | <b>28</b>      |
| Potential                     | 28                   | 28   | 28              | <b>28</b>      | 28                    | 28   | 28              | <b>28</b>      |
| Nesting attempts              | 9                    | 11   | 11 <sup>1</sup> | <b>31</b>      | 15                    | 11   | 18 <sup>1</sup> | <b>44</b>      |
| Occupied                      | 9                    | 11   | 10 <sup>1</sup> | --             | 15                    | 11   | 17 <sup>1</sup> | --             |
| (Occupied/Potential)          | 32%                  | 39%  | 36%             | <b>36%</b>     | 54%                   | 39%  | 61%             | <b>51%</b>     |
| Hatched                       | 7                    | 2    | 4               | <b>13</b>      | 12                    | 8    | 15              | <b>35</b>      |
| (Hatched/Nesting attempts)    | 78%                  | 18%  | 36%             | <b>42%</b>     | 80%                   | 73%  | 83%             | <b>80%</b>     |
| Depredated                    | 2                    | 8    | 6               | <b>16</b>      | 1                     | 2    | 0               | <b>3</b>       |
| (Depredated/Nesting attempts) | 22%                  | 73%  | 55%             | <b>52%</b>     | 7%                    | 18%  | 0%              | <b>7%</b>      |
| Abandoned                     | 0                    | 1    | 1               | <b>2</b>       | 2                     | 1    | 3               | <b>6</b>       |
| (Abandoned/Nesting attempts)  | 0%                   | 9%   | 9%              | <b>6%</b>      | 13%                   | 9%   | 17%             | <b>14%</b>     |

<sup>1</sup>Two nesting attempts in one site (*see methods*).

Table 3: Breeding indices for Xantus's Murrelet nest sites in sample areas outside of sea caves at Anacapa Island, California, after eradication of Black Rats.

| Nest Site Summary                           | 2003      | 2004     | 2005           | 2003-05        |
|---------------------------------------------|-----------|----------|----------------|----------------|
| Tagged & Monitored                          | 2         | 4        | 9 <sup>1</sup> | 9 <sup>1</sup> |
| Potential                                   | 7         | 8        | 9 <sup>1</sup> | 9 <sup>1</sup> |
| Nesting attempts                            | 2         | 2        | 8              | 12             |
| Occupied<br>(Occupied/Potential)            | 2<br>29%  | 2<br>25% | 8<br>89%       | --<br>50%      |
| Hatched<br>(Hatched/Nesting attempts)       | 2<br>100% | 1<br>50% | 8<br>100%      | 11<br>92%      |
| Depredated<br>(Depredated/Nesting attempts) | 0<br>0%   | 0<br>0%  | 0<br>0%        | 0<br>0%        |
| Abandoned<br>(Abandoned/Nesting attempts)   | 0<br>0%   | 1<br>50% | 0<br>0%        | 1<br>11%       |

<sup>1</sup>Excludes one tagged site destroyed by a landslide (*see text*).

Table 4: Nest initiation dates for Xantus's Murrelets at Anacapa Island in 2000-05, using monitored nest sites and observations of family groups departing the island.

| Year              | Nest Initiation Date<br>Mean ( $\pm$ sd) | No. Of Nests/Observations;<br>Range of Initiation Dates |
|-------------------|------------------------------------------|---------------------------------------------------------|
| 2000              | 30 Mar ( $\pm$ 11 d)                     | 9; 16 Mar - 14 Apr                                      |
| 2001              | 13 Apr ( $\pm$ 15 d)                     | 12; 25 Mar - 5 May                                      |
| 2002 <sup>1</sup> | 10 Apr ( $\pm$ 16 d)                     | 11; 7 Mar - 3 May                                       |
| 2003              | 9 Apr ( $\pm$ 11 d)                      | 23; 26 Mar - 5 May                                      |
| 2004 <sup>2</sup> | 1 May ( $\pm$ 20 d)                      | 12; 6 Apr - 3 Jun                                       |
| 2005 <sup>1</sup> | 2 May ( $\pm$ 14 d)                      | 26; 11 Apr - 2 Jun                                      |

<sup>1</sup> Data include lay dates for two nesting attempts in the same site in Respiring Chimney Cave in 2002 and 2005.

<sup>2</sup> Data from 2004 includes late evidence of nesting from two sites not found until 2005 and not included in 2004 annual report.



Appendix 1. Individual histories for each Xantus's Murrelet nest monitored at Anacapa Island, 2000-05. Nest activity in monitored sites each year is classified as A = active or 0 = not active. Summary includes nests fate and the most reliable evidence of nesting observed in active sites each year which are coded as follows: [nest fates] hatched = (H); depredated = (D); abandoned = (Ab); unknown = (U); [evidence of nesting] adult in nest (ad); whole egg (egg); hatched eggshell fragments in or near site (hef); broken eggshell fragments in or near site (bef). Murrelet eggshell fragments not associated with potential nest sites were found in several caves in some years and are indicated by an (●) in the upper right corner. Murrelet eggshell fragments were found and potential nest sites tagged in ten sea caves during nest searches conducted after the breeding season in 1994-97. These ten sea caves were included in the initial nest monitoring program begun in 2000. Nest searches in other shoreline areas did not begin until 2003-05.

| Sea cave or shoreline plot | Nest number | Year first active | Prior nest numbers | 2000       | 2001        | 2002       | 2003     | 2004       | 2005       | Notes                                                    |
|----------------------------|-------------|-------------------|--------------------|------------|-------------|------------|----------|------------|------------|----------------------------------------------------------|
| Refuge                     | 1           | 1994-96           | #254               | 0          | A-D (bef) ● | 0          | 0        | 0          | 0          |                                                          |
|                            | 2           | 1994-96           | #257               | 0          | 0           | 0          | 0        | 0          | 0          |                                                          |
|                            | 3           | 1994-96           | #256               | —          | —           | A-Ab (egg) | 0        | 0          | 0          | Site not noted in 2000-01                                |
|                            | 4           | 2000              | #581               | A-D (bef)  | A-D (bef)   | 0          | 0        | 0          | 0          |                                                          |
|                            | 5           | 1994-96           | #259               | 0          | 0           | 0          | 0        | 0          | A-H (ad)   |                                                          |
|                            | —           | 1994-96           | #255               | —          | —           | —          | —        | —          | —          | Site not found after 1997                                |
|                            | —           | 1994-96           | #258               | —          | —           | —          | —        | —          | —          | Site not found after 1997                                |
| Lava Bench #1              | 1           | 2000              | #576               | A-H (ad) ● | 0           | ● A-D (ad) | A-H (ad) | A-H (ad)   | ● A-H (ad) | Dead adult in site in 2001                               |
|                            | No Tag      | 2005              |                    | —          | —           | —          | —        | —          | A-Ab (egg) | Open site not tagged                                     |
| Lava Bench #2              | 1           | 1994-96           | #301; #555         | A-H (ad)   | A-D (bef)   | A-D (ad)   | A-H (ad) | A-D (ad)   | A-H (ad)   |                                                          |
| Respiring Chimney          | 1(1)        | 1994-96           | #260; #551; #554   | A-H (ad)   | A-H (ad)    | A-D (bef)  | A-H (ad) | A-H (ad)   | A-H (ad)   | Two nesting attempts in nest #1 in 2002 and 2005.        |
|                            | 1(2)        |                   |                    |            |             | A-H (ad)   |          |            | A-H (ad)   |                                                          |
|                            | 2           | 2001              | #548               | —          | A-Ab (ad)   | A-D (egg)  | A-H (ad) | 0          | A-Ab (ad)  |                                                          |
| Lonely at the Top          | 3           | 2001              | #550               | —          | A-D (bef)   | 0          | 0        | 0          | 0          |                                                          |
|                            | 1           | 2003              |                    | —          | —           | ●          | A-H (ad) | A-D (ad)   | 0          | ●                                                        |
| Confusion                  | 2           | 2003              |                    | —          | —           | —          | A-H (ad) | A-H (ad)   | A-H (ad)   |                                                          |
|                            | —           | —                 | —                  | —          | —           | —          | —        | —          | —          | No active sites found                                    |
| Pinnacle                   | 1           | 1994-96           | #250               | —          | A-H (ad)    | 0          | 0        | 0          | 0          | Site not noted in 2000                                   |
|                            | 2           | 2003              |                    | —          | —           | —          | A-H (ad) | A-Ab (egg) | A-H (ad)   | Late nest in 2004, evidence found in 2005                |
|                            | 3a          | 2003              |                    | —          | —           | —          | A-H (ad) | 0          | A-Ab (egg) |                                                          |
|                            | 3b          | 2004              |                    | —          | —           | —          | —        | A-H (hef)  | A-H (ad)   | Late nest in 2004, nest and evidence first found in 2005 |

# Appendix 1: continued

| Sea Cave or<br>Shoreline Plot | Nest<br>number | Year first<br>active/found | Prior nest<br>numbers | 2000       | 2001      | 2002      | 2003      | 2004       | 2005      | Notes                                                                                                                |
|-------------------------------|----------------|----------------------------|-----------------------|------------|-----------|-----------|-----------|------------|-----------|----------------------------------------------------------------------------------------------------------------------|
| Moss                          | 1              | 2000                       | #579a                 | A-H (ad)   | A-U (ad)  | A-H (ad)  | A-H (ad)  | A-H (ad)   | A-H (ad)  |                                                                                                                      |
|                               | 2              | 2000                       | #579b                 | A-H (ad)   | A-D (ad)  | A-H (ad)  | A-Ab (ad) | A-H (ad)   | A-H (ad)  |                                                                                                                      |
|                               | 3              | 2000                       | #580                  | A-U (ad)   | A-U (ad)  | A-H (ad)  | A-H (ad)  | A-H (ad)   | A-H (ad)  |                                                                                                                      |
|                               | 4              | 2003                       |                       | —          | —         | —         | A-H (ad)  | 0          | A-H (hef) |                                                                                                                      |
| Aerie                         | 1              | 2000                       | #578                  | A-H (ad) ● | A-D (bef) | A-D (bef) | 0         | 0          | 0         | ● PIGU nest in 2003-05                                                                                               |
|                               | 2              | 2003                       |                       | —          | —         | —         | A-U (ad)  | 0          | 0         |                                                                                                                      |
|                               | 3              | 2003                       |                       | —          | —         | —         | A-H (ad)  | A-H (ad)   | A-H (ad)  |                                                                                                                      |
|                               | 1101           | 2005                       |                       | —          | —         | —         | —         | —          | A-H (ad)  |                                                                                                                      |
|                               | —              | 1994-96                    | #251                  | 0          | —         | —         | —         | —          | —         | Tag #251 and #577 lost; location<br>for #251 uncertain, presumed<br>site for #577 is monitored but<br>not yet tagged |
|                               | —              | 2000                       | #577                  | A-H (ad)   | 0         | A-D (bef) | 0         | 0          | 0         |                                                                                                                      |
| Keyhole                       | 1              | 2003                       |                       | —          | —         | —         | A-Ab (ad) | 0          | 0         | PIGU usurped nest in 2003 and<br>used site in 2004-05                                                                |
|                               | 1103           | 2005                       |                       | —          | —         | —         | —         | —          | A-H (ad)  |                                                                                                                      |
| Landing Cove                  | 1              | 2003                       |                       | —          | —         | —         | A-H (ad)  | 0          | 0         |                                                                                                                      |
|                               | 2              | 2004                       |                       | —          | —         | —         | —         | A-H (hef)  | A-H (ad)  |                                                                                                                      |
|                               | 1102           | 2005                       |                       | —          | —         | —         | —         | —          | A-H (ad)  |                                                                                                                      |
|                               | 1104           | 2005                       |                       | —          | —         | —         | —         | —          | A-H (ad)  |                                                                                                                      |
|                               | 1105           | 2005                       |                       | —          | —         | —         | —         | —          | A-H (ad)  |                                                                                                                      |
|                               | 1106           | 2005                       |                       | —          | —         | —         | —         | —          | A-H (ad)  |                                                                                                                      |
| Rockfall Cove                 | 1107           | 2005                       |                       | —          | —         | —         | —         | —          | A-H (ad)  |                                                                                                                      |
|                               | 1108           | 2005                       |                       | —          | —         | —         | —         | —          | A-H (ad)  |                                                                                                                      |
| East Fish Camp                | 1              | 2004                       |                       | —          | —         | —         | —         | A-Ab (egg) | —         | Landslide destroyed site winter<br>2004-05                                                                           |
| Cat Rock                      | 1              | 2003                       |                       | —          | —         | —         | A-H (ad)  | 0          | A-H (ad)  |                                                                                                                      |

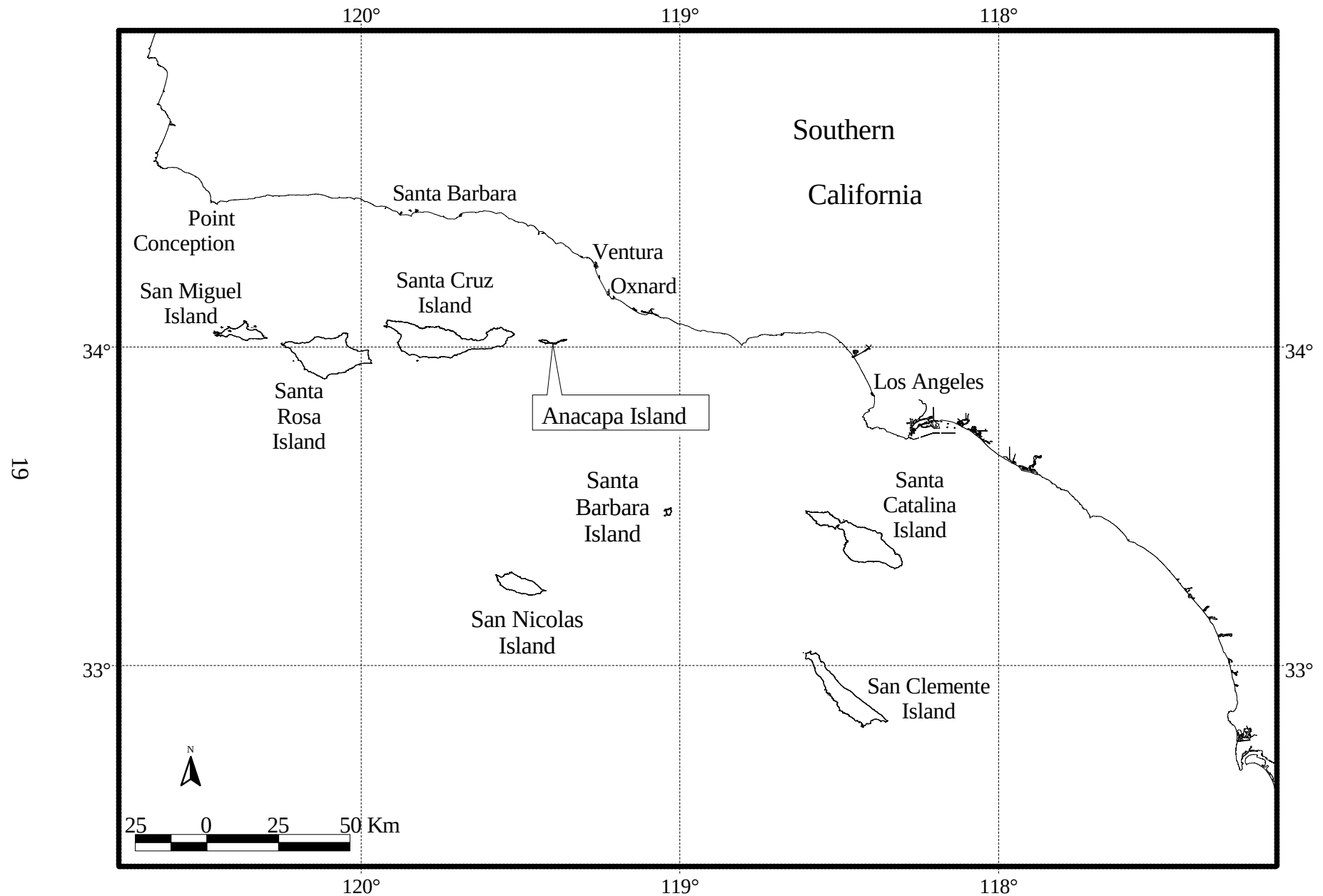


Figure 1. Map of the Southern California Bight and Channel Islands, showing the location of Anacapa Island

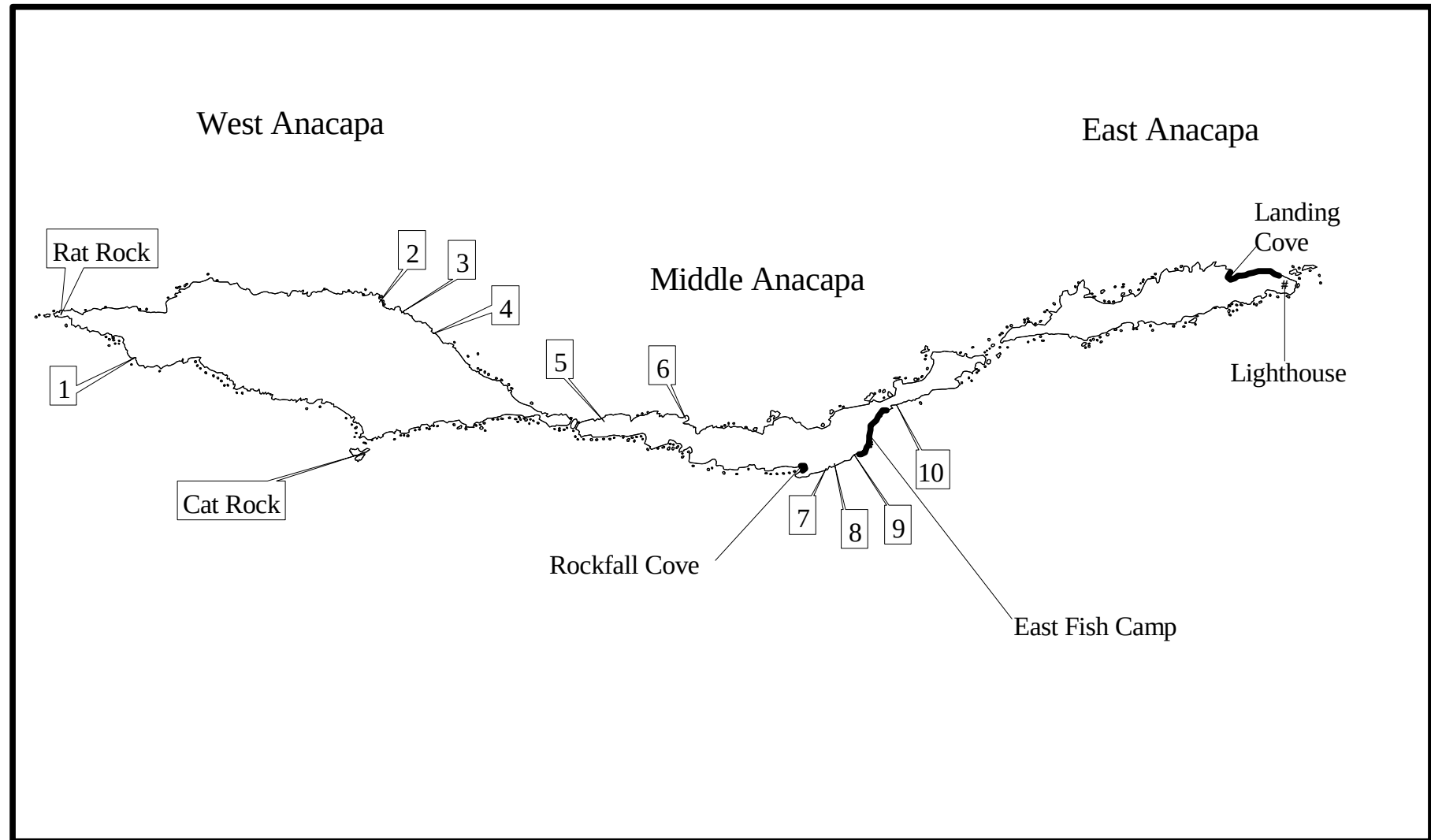


Figure 2. Map of Anacapa Island indicating ten sea caves monitored in 2000-2005 and Cat Rock, Rat Rock and other areas (black outline) monitored in 2003-05. Sea caves are numbered: 1) Lonely at the Top; 2) Confusion; 3) Pinnacle; 4) Moss; 5) The Aerie; 6) Keyhole; 7) Respiring Chimney; 8) Lava Bench #2; 9) Lava Bench #1; 10) Refuge.

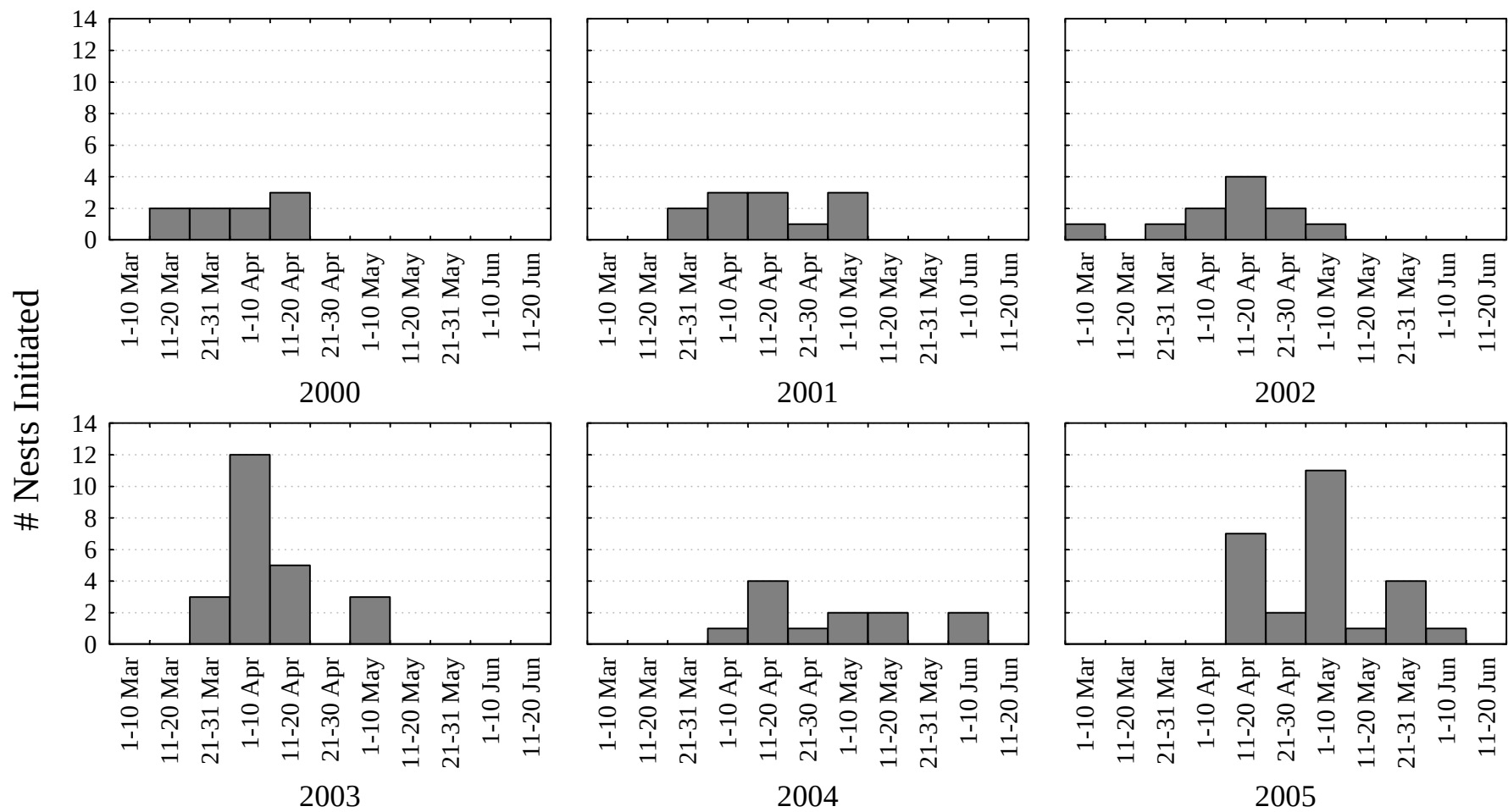


Figure 3. Timing of breeding for Xantus's Murrelets at Anacapa Island, California, 2000-05. Nesting phenology determined from monitored sites and observations of family groups departing the island.

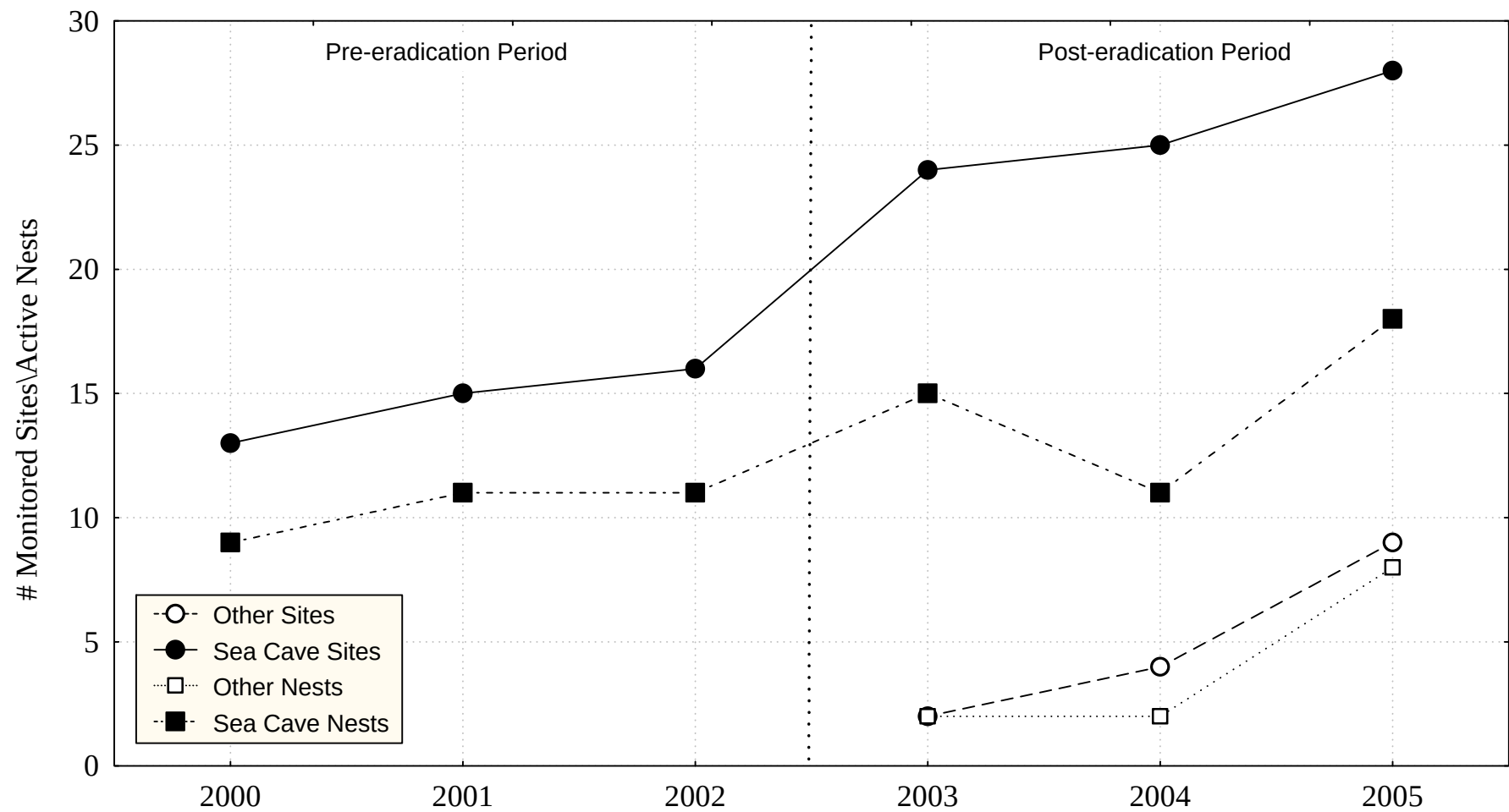


Figure 4. Number of monitored sites (sites) and active nests (nests) in sea caves and other sampled areas for Xantus's Murrelets at Anacapa Island, California, 2000-05.

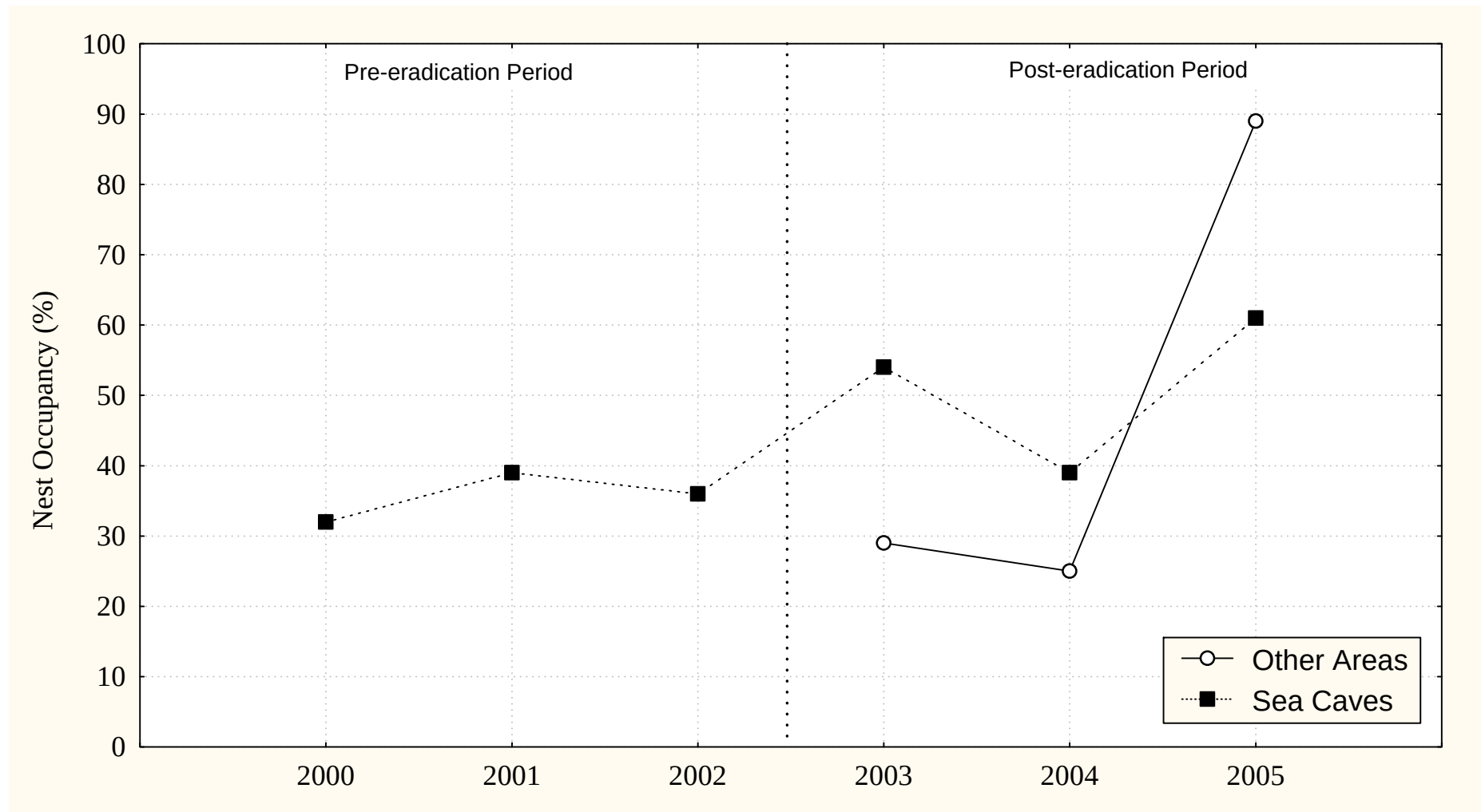


Figure 5. Nest occupancy (%) in sea caves and other sampled areas for Xantus's Murrelets at Anacapa Island, California, 2000-05.

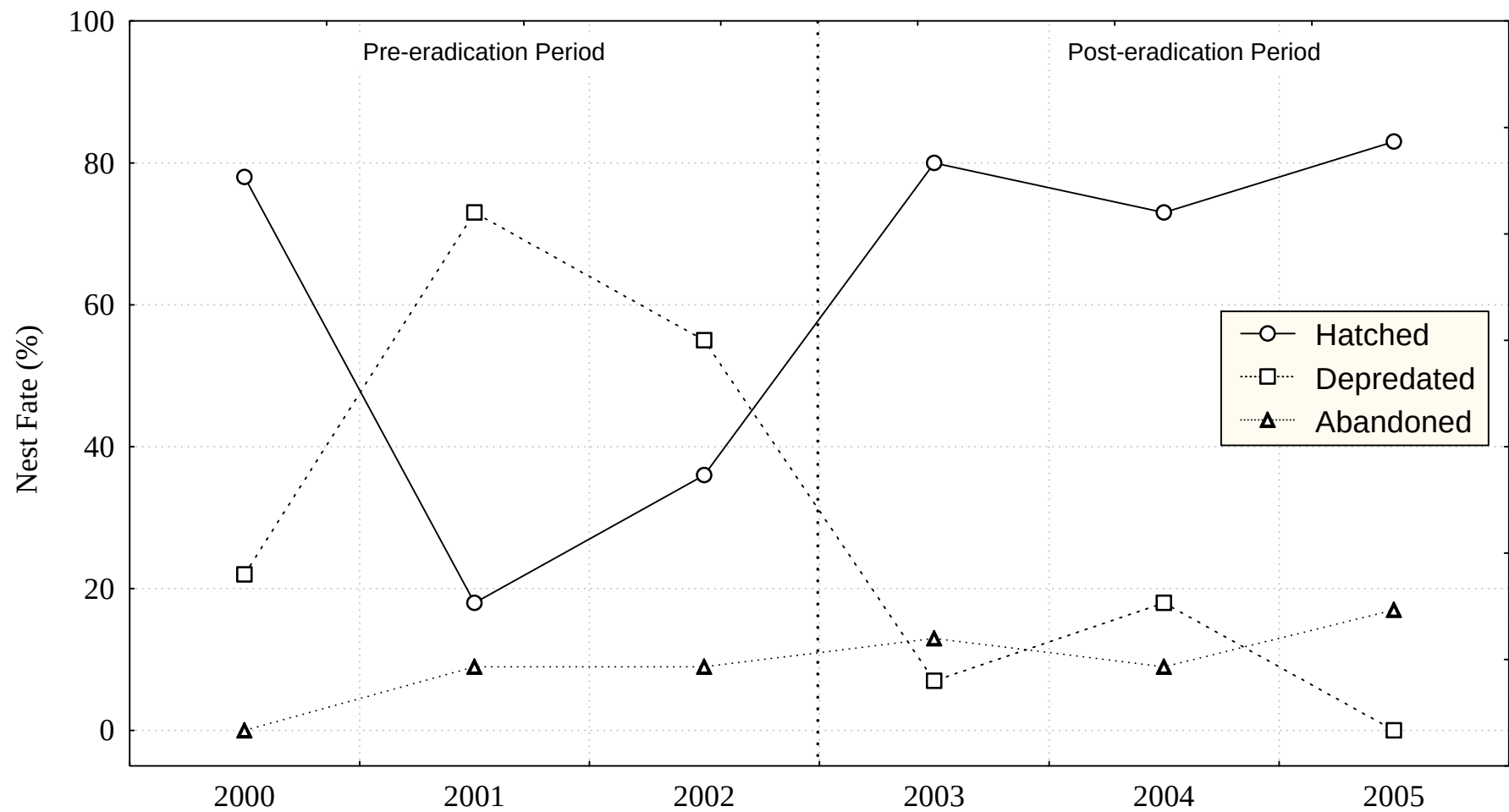


Figure 6. Xantus's Murrelet nest fates (hatched, depredated and abandoned nests) in sea caves at Anacapa Island, California, 2000-05.