BREEDING OF CASSIN'S AUKLETS *PTYCHORAMPHUS ALEUTICUS* AT ANACAPA ISLAND, CALIFORNIA, AFTER ERADICATION OF BLACK RATS *RATTUS RATTUS*

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SUMMARY

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The first confirmed Cassin's Auklet *Ptychoramphus aleuticus* nests at Anacapa Island, California, were found on Rat Rock in May 2003, less than one year after the eradication of Black Rats *Rattus rattus* in November 2002. By 2012, auklet nesting had been detected in six discrete shoreline areas on the West and East Anacapa islets. We discovered a total of 42 auklet nests (i.e. sites occupied in at least one breeding season) from 2003 to 2012, including 17 confirmed nests (adults, chicks or eggs/eggshells observed) and 25 nests where breeding was inferred (fresh digging, guano streaking or strong auklet odor). Suspected breeding by auklets at Anacapa was first noted in June 1910. By the mid-20th century, rats had restricted breeding auklets to, at most, a few isolated pairs nesting on inaccessible cliffs. However, the population may have been extirpated before rat eradication, as we found no evidence of auklets nesting in any current breeding areas during surveys in 1991, 1994, 1997 and 2000. Subadult and adult auklets captured during nocturnal mist-netting at two current breeding areas in 1994 were likely offspring of isolated cliff-nesting pairs or birds from colonies on nearby islands. Once rats were removed, prospecting by subadult auklets may have facilitated initial colony growth and occupation of some previously unused breeding habitats. Continued searches and nest monitoring are needed to further document post-eradication colony growth.

Keywords: Anacapa Island, Black Rat, Cassin's Auklet, eradication, introduced predator, *Ptychoramphus aleuticus, Rattus rattus*, restoration

INTRODUCTION

Few detailed studies have examined the pre-eradication impacts of introduced predators on seabirds and their post-eradication responses (Lavers *et al*. 2010, Buxton *et al*. 2014). The eradication of Black Rats *Rattus rattus* from Anacapa Island (hereafter "Anacapa"), Channel Islands National Park (CINP), California, provided a valuable opportunity to study the post-eradication recovery of affected seabirds. Rats likely caused serious damage to a poorly documented population of Cassin's Auklets *Ptychoramphus aleuticus* (hereafter "auklets") at Anacapa Island after the rodents were introduced, probably as a result of a shipwreck in 1853 (Collins 1979; K. Faulkner, pers. comm.). The presence of auklets at Anacapa was first reported in June 1910 by Willett (1910), who noted that they were "common at night and undoubtedly breeding somewhere on the island, but we did not locate the nesting colony." Throughout the 20th century, direct evidence of nesting proved elusive because rats had either extirpated auklets or restricted the remnant population to coastal cliffs, where small numbers of breeding auklets could escape rat predation but also remained undetected by researchers (McChesney & Tershy 1998, Whitworth *et al*. 2013). Naturalists and egg collectors found no auklet nests during visits from 1910 to 1938 (Hunt *et al*. 1979). Nor were auklets found during seabird surveys in 1975–1977 (Hunt *et al*. 1979) and 1991 (Carter *et al*. 1992). However, it should be noted that no specific efforts to detect auklets were made during these studies. Hunt *et al*. (1979) considered it "possible, though unlikely that a small population existed on these islands" despite the presence of rats. Carter *et al*. (1992) considered that rats had likely extirpated breeding auklets and prevented recolonization. Eight auklets captured during nocturnal mistnetting on East and West Anacapa in 1994 (H. Carter, unpubl. data) provided the first recent evidence of visitation by small numbers of auklets, although the source of these birds was not known. However, auklet nests were not found on Anacapa during extensive searches for crevice and burrow-nesting seabirds in a variety of habitats in 1994–2002 (Whitworth *et al*. 2005, 2013; H. Carter, unpubl. data).

CINP and Island Conservation successfully eradicated rats at Anacapa (Howald *et al*. 2009) in 2002 as part of the Anacapa Island Restoration Program (AIRP) managed by the American Trader Trustee Council (ATTC 2001). Restoration of the remnant Scripps's Murrelet *Synthliboramphus scrippsi* (hereafter "murrelet") population was the primary seabird-related justification for the AIRP, and extensive baseline and post-eradication population monitoring was conducted to measure the benefits of rat eradication. Murrelets

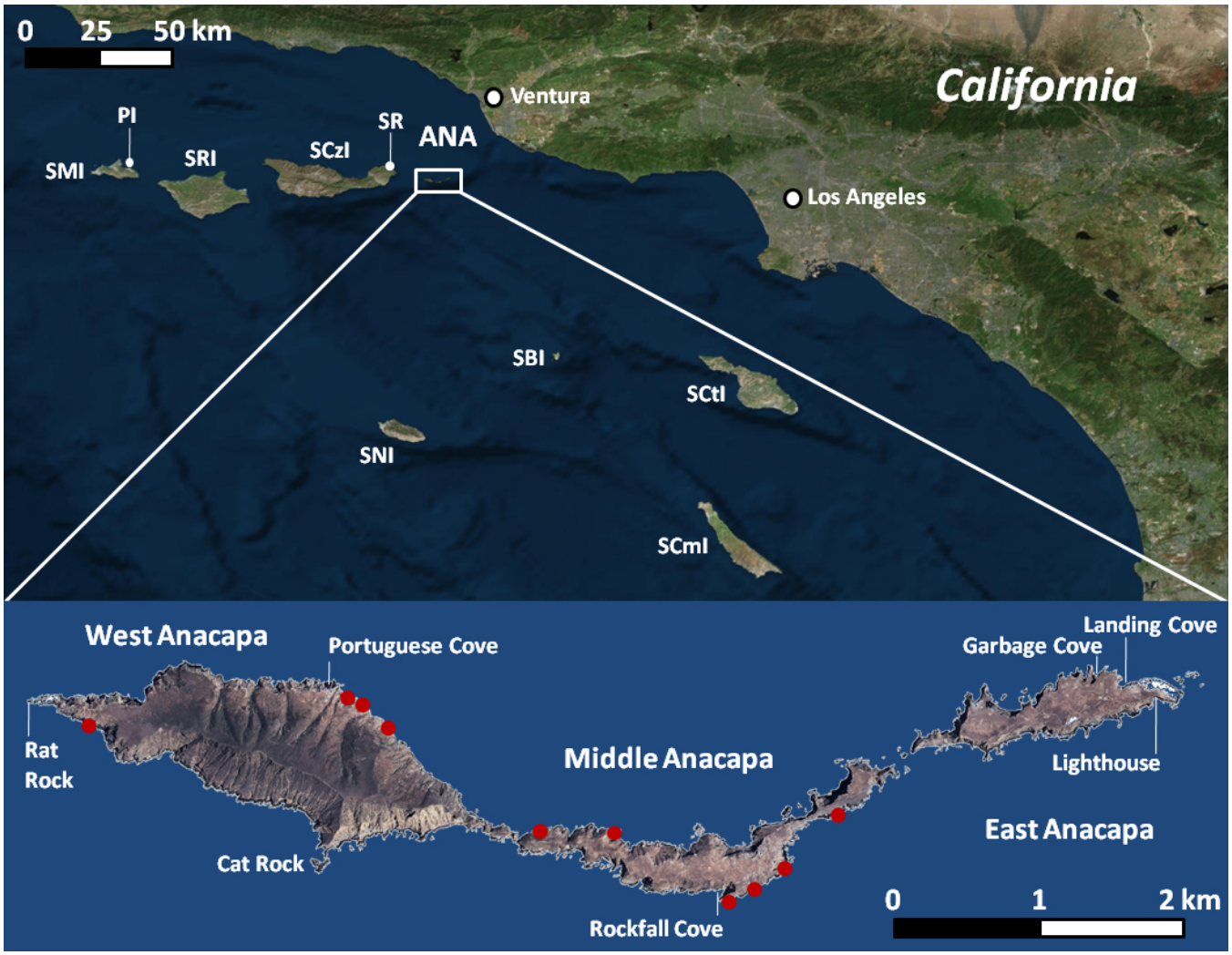

Fig. 1. Anacapa Island (ANA), located among the California Channel Islands; San Miguel Island (SMI), Prince Island (PI), Santa Rosa Island (SRI), Santa Cruz Island (SCzI), Scorpion Rock (SR), Santa Barbara Island (SBI), San Nicolas Island (SNI), Santa Catalina Island (SCtI) and San Clemente Island (SCmI). Inset: Cassin's Auklet nest search areas and sea caves (red circles).

TABLE 1
Cassins's Auklet nests at Anacapa Island, California in 1991–2012

Area	1991	1994	1996	1997	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Total
Rat Rock	–[a]	0[b]		0[c]	–	–	–	2	1	2	–	–	–	3	11	17	16	18
Landing Cove	0	0[b]	–	0[c]	–	–	–	0	0	0	0	0	2	3	3	–	–	3
Portuguese Cove	–	–	–	–	–	–	–	–	–	–	–	–	–	5[b]	11	10+[c]	12	12
Cat Rock	0	0	–	0[c]	0	–	–	0	0	0	0	0	0	0	1	–	–	1
Lighthouse	–	0	–	0[c]	–	–	–	0	–	–	–	–	–	0[b]	–	7	–	7
Garbage Cove	–	0[c]	–	0[c]	0	–	–	0	–	–	–	–	–	–	–	1	–	1
Rockfall Cove	–	–	–	–	–	–	–	–	–	0	0	0	0	0	0	0	0	0
Sea Caves[d]	–	0[c]	0	0[c,e]	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	2	1	2	0	0	2	11	26	35	28	42

[a] Indicates years in which searches were not conducted.
[b] Nocturnal visitation by auklets.
[c] Checked after the breeding season only (July–October).
[d] All 10 sea caves combined.
[e] Unidentified small white eggshell fragment found in Pinnacle Cave.

exhibited improved hatching success, an increase in the number of nests in remnant breeding areas and occupation of vacant breeding habitats immediately after eradication (Whitworth *et al*. 2013). In this paper, we collate opportunistic observations of breeding by auklets at Anacapa obtained during murrelet monitoring in 2003–2012 (Whitworth *et al*. 2005, 2013; L. Harvey, unpubl. data), examine evidence of colony visitation and possible breeding in 1994–2002 and discuss factors affecting occupation of vacant breeding habitats and colony growth after eradication.

METHODS

Study area

Anacapa Island (34°01′N, 119°22′W), California, lies about 20 km off the southern California coast, southwest of Ventura, and is the easternmost and smallest of the northern four California Channel islands (Fig. 1). Anacapa is composed of three small islets (Fig. 1) separated by narrow channels, forming an island chain approximately 8 km long. The steep and rocky coastline is indented by more than 100 sea caves. West Anacapa is the largest (1.7 km^2) and highest (284 m) of the three islets, followed by Middle Anacapa (0.6 km^2, 99 m) and East Anacapa (0.5 km^2, 73 m). Anacapa is managed by CINP, which maintains quarters for staff and facilities for campers on East Anacapa, but the other islets are uninhabited.

Nest searches

We used hand-held flashlights to inspect suitable rock crevices and burrows in seven shoreline areas and 10 sea caves (Table 1, Fig. 1). Most searches were conducted during the murrelet and auklet breeding season (generally March–June), although searches of sea caves and Garbage Cove in 1994, all areas in 1997, Portuguese Cove in 2009 and 2011, and the Lighthouse in 2009 were conducted after the breeding season (Table 1). The timing of breeding of auklets and murrelets typically overlaps in southern California, but auklet egg laying can commence as early as December and extend into June; in productive years, two broods can be raised at colonies in California and Baja California (Hunt *et al*. 1979, Ainley *et al*. 1990, Manuwal & Thoreson 1993, Adams *et al*. 2004b). The timing of our surveys varied, and not all areas were searched each year (Table 1). Nest searches were conducted roughly every two weeks in murrelet breeding areas (i.e. sea caves, Landing Cove, Cat Rock and Rockfall Cove), while other areas were searched when time and conditions permitted. Limited visibility prevented confirmation of breeding (i.e. adults, chicks or an egg/eggshell observed) in many deep crevices, but breeding could often be inferred by fresh digging, guano streaking or strong auklet odor. Auklet nests at Rat Rock and Landing Cove were marked with numbered tags, but nests in other areas were not marked. Breeding areas were accessed with a 3.8 m inflatable boat.

RESULTS

Breeding by Cassin's Auklet at Anacapa Island was first confirmed in May 2003 when we found chicks in two crevices on the north-central shore of Rat Rock (Table 1, Fig. 2). Extensive searches in 2003 indicated Rat Rock was the only auklet breeding area at Anacapa that year. Auklet nesting was limited to Rat Rock from 2003 to 2007, although not all areas were searched each year. The first nests outside Rat Rock were not discovered until 2008, when two nests were documented on the Landing Cove cliffs (Fig. 3). By 2012, we had found 42 auklet nests in six shoreline areas, three areas each on West Anacapa and East Anacapa (Table 1), including 17 nests in which adult auklets, chicks or eggs/eggshells were observed ("confirmed" nests), and 25 nests in which breeding was inferred from fresh digging, guano and auklet odor. Nests were not found in any sea caves or Rockfall Cove. Presence of endemic deer mice *Peromyscus maniculatus anacapae* and former use by rats (e.g. feces and food caches) was found in all of the areas searched. Details of nest searches in all areas examined at Anacapa from 1991 to 2012 are provided in Table 1 and Appendix 1 (available on the website).

DISCUSSION

Benefits of rat eradication

The first documented nesting of Cassin's Auklet in 2003 and subsequent growth of a small population from 2003 to 2012 has demonstrated additional unexpected benefits of rat eradication for

Fig. 2. Rat Rock, West Anacapa Island, and the approximate locations of Cassin's Auklet nests found in May 2003 (1, 2) and March 2009 (3).

Fig. 3. Landing Cove Cliffs and Lighthouse, East Anacapa Island, and the approximate locations of Cassin's Auklet nests found in May 2008 (1, 2).

seabirds at Anacapa Island, beyond those expected and already reported for Scripps's Murrelets (Whitworth *et al*. 2013). Auklets and murrelets both nest in concealed sites, but auklets raise chicks on land. As a result, their nests are more likely to be betrayed by conspicuous auditory, visual and olfactory cues that make them more vulnerable to rat predation (Thoreson 1964). Thus, while a relatively large remnant murrelet population persisted in some rodent-accessible habitats when rats inhabited Anacapa (about 200 pairs; Whitworth & Carter 2014), the auklet population was completely or nearly extirpated between 1910 and 1975. After rat eradication, we discovered a total of 42 auklet nests in six discrete breeding areas from 2003 to 2012. Assuming first breeding at three to four years (Pyle 2001), auklet chicks fledged at Anacapa after 2002 likely contributed to the strong post-eradication surge in nesting in 2008–2012 (Table 1). Because our nest monitoring data were limited, we could not measure auklet hatching or fledging success, but a similar post-eradication surge in nesting by murrelets was likely related to higher hatching success since 2003, leading to greater local recruitment in subsequent years (Whitworth *et al*. 2013).

The reoccupation of Langara Island (hereafter "Langara"), British Columbia, Canada, provided another example of the benefits of rat eradication for Cassin's Auklet (Regehr *et al*. 2007). Black Rats were introduced on Langara in the early 20th century (first noted in 1946), followed by Norway Rats *R. norvegicus* a few decades later (first noted in 1981; Bertram & Nagorsen 1995). The auklet population on Langara and adjacent Cox and Lucy islands was extirpated by 1981 (Drent & Guiguet 1961, Rodway 1991). After the eradication of rats in 1995, auklets were not detected during nesting surveys in 1999, but small numbers of auklets had recolonized Langara by the time the next surveys were conducted in 2004 (Regehr *et al*. 2007).

Occupation of vacant breeding habitats

Nocturnal visitation by non-breeding auklets at Rat Rock on 15 May 1994 suggested prospecting behavior that likely facilitated the initial occupation of this vacant breeding habitat in 2003, within one year after eradication. Two auklets without brood patches but with mostly white irides (indicating adults or older subadults; Manuwal 1978) were captured in a storm-petrel (*Oceanodroma* spp.) mist-net (H. Carter, unpubl. data). Six auklets were also captured at Landing Cove in April and May 1994, although nests were not discovered there until 2008. On 16 April 1994, five non-breeding auklets without brood patches were captured in a mist-net while apparently prospecting at the bottom of the Landing Cove cliffs. Three of these five auklets had mostly dark irises, indicating younger subadults (1–2 years), while the other two had white irides. On 2 May 1994, one breeding adult auklet with a white iris (Fig. 4) and brood patches was captured in a mist-net at the top of the cliffs.

The frequency, extent and source of nocturnal visitation was not studied before eradication; therefore, we could not determine whether the initial prospectors at Rat Rock and Landing Cove were (1) offspring from a remnant population that nested in nearby inaccessible cliffs or (2) individuals from nearby colonies at Scorpion Rock (10 km west), Prince Island (82 km west) and Santa Barbara Island (66 km south). The breeding adult captured at Landing Cove in 1994 suggested that local breeding by a few pairs may have occurred somewhere at Anacapa, since breeding adults rarely visit other colonies. However, like some other alcids, subadult auklets sometimes prospect at non-natal colonies, usually near their natal colonies (e.g. Gaston 1992, Halley & Harris 1993), and enhanced inter-colony movements by adults and subadults can occur under unusual conditions (e.g. Harris *et al*. 1996).

The timing of post-eradication occupation of vacant breeding habitats by auklets and murrelets in 2003–2102 was not consistent. Auklet nests were found within a year of eradication at Rat Rock, but the first murrelet nest was not found until 2012 (L. Harvey, unpubl. data). In contrast, murrelet nests were found within one year of eradication at Landing Cove and Cat Rock (Whitworth *et al*. 2005, 2013), but there was a seven to eight year lag between eradication and auklet nesting in these areas. The lag between eradication and nesting at Landing Cove was somewhat surprising given documented auklet visitation in this area in 1994. We could not reliably determine when auklets or murrelets began nesting in Portuguese Cove because post-eradication searches did not begin until 2009. However, the relatively large number of auklet nests found there in 2009 (Table 1) suggests they likely occupied this area (and perhaps other breeding areas not monitored consistently after eradication) for several years before they were discovered. It is unclear why auklets have not yet occupied Rockfall Cove, an area with abundant nesting habitat that has seen considerable growth in the number of murrelet nests post-eradication (Whitworth *et al*. 2013). The lack of auklet nesting in sea caves is not surprising, as sea caves do not appear to be suitable auklet breeding habitat at any southern California island (Carter *et al*. 1992).

Potential for future colony growth

Thus far, most auklet nests at Anacapa have been found in rock crevices, but continued population growth for auklets and other crevice-nesting seabirds will eventually limit the availability of suitable crevices in current breeding areas. Some additional colony growth is possible at Rat Rock, Landing Cove, the Lighthouse, Portuguese Cove, and to a lesser extent Garbage Cove, where suitable vacant nesting crevices are still available. Little growth is expected on Cat Rock because of its small size

Fig. 4. Incubating adult Cassin's Auklet in nest #2 on Rat Rock, West Anacapa Island. Note the white iris typical of breeding adults and older subadults.

and few suitable breeding crevices. Burrow-nesting auklets could expand onto gently sloping grasslands with deep soils on the upper island, which would permit a much larger population (assuming prey conditions are favorable in the future; Ainley *et al*. 1990, Lee *et al*. 2007). Auklets commonly nest in soil burrows at Prince Island and have nested in soil and guano burrows at Scorpion Rock and Santa Barbara Island in the past (Grinnell 1897, Howell 1917, Hunt *et al*. 1979, Carter *et al*. 1992). However, there is no evidence that auklets ever nested in burrows on upper island habitats at Anacapa. Past anthropogenic impacts from ranching and other activities have altered the soils and vegetation, making the current suitability of these habitats for burrow nesting auklets unclear.

Infrequent nest checks and poor visibility in many crevices made it difficult to determine auklet egg-laying, hatching and fledging in 2003–2012. The only failed nests were one abandoned egg noted on Rat Rock in 2004 and depredated (or scavenged) eggs at Portuguese Cove in 2009 and 2012. We observed chicks in many nests and documented several instances of apparent second clutches in 2009 and 2010, which indicated excellent breeding conditions (Ainley *et al.* 1990). More frequent monitoring and extensive nest searches will be needed to fully document future growth, expansion and reproductive success of this recovering auklet population. Continued growth of the auklet population will depend on (1) adequate reproductive success and survival, (2) availability of suitable nesting habitats, (3) adequate prey abundance and availability, and (4) relatively low levels of anthropogenic impacts (e.g. oil spills, bright lights [Carter *et al*. 2000, Adams 2008]).

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