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Source: Monographs of the Western North American Naturalist, 7(1) : 321-338

Published By: Monte L. Bean Life Science Museum, Brigham Young University

URL: <https://doi.org/10.3398/042.007.0124>

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STATUS, DISTRIBUTION, AND CONSERVATION OF SCRIPPS'S MURRELET AT SANTA CATALINA ISLAND, CALIFORNIA

Darrell L. Whitworth^{1,2,6}, Harry R. Carter^{1,2,4}, Tyler M. Dvorak³, Linda S. Farley^{3,5}, and Julie L. King³

ABSTRACT.—The small population of Scripps's Murrelets (*Synthliboramphus scrippsi*) at Santa Catalina Island, California, has been restricted for at least several millennia to isolated pairs nesting in cliff and shoreline habitats that are mostly inaccessible to island fox (*Urocyon littoralis catalinae*). Prior to 1994, the only evidence of murrelets breeding at Catalina was a single nest reportedly found on Bird Rock in 1967. In 1994–1995, a larger and more widespread population estimated at 25–75 pairs was indicated through vocal detection surveys of murrelets attending nocturnal at-sea congregations in nearshore waters near breeding areas. Murrelets were heard at 11 of 25 survey stations, with highest vocal activity between Land's End and Ribbon Rock (6–62 detections per survey). In 2004 and 2012, round-island spotlight surveys better assessed the distribution and abundance of murrelets in congregations, with 101 and 291 individuals, respectively, observed along the 82-km transect. Highest numbers in 2012 suggest a current breeding population of roughly 100–200 pairs at Catalina, the fourth largest colony in southern California. Congregations were strongly associated with coastal cliffs between (1) Isthmus Cove and Twin Rocks and (2) Iron Bound Bay and Catalina Harbor. In 2000–2013, night-lighting captures of 79 birds in congregations recorded 10 (13%) murrelets with brood patches, usually indicative of egg-laying. During captures in 2008 and spotlight surveys in 2012, three family groups (adults with small downy chicks) departing island nests were observed in nearshore waters. No nests were found during searches on offshore rocks (including Bird Rock) in 1991–1996, but 7 nests were discovered in 2012–2013 during searches of boat-accessible shoreline cliffs between Isthmus Cove and Twin Rocks. Overall, 6 of 8 clutches (75%) with known fates were successful, but evidence of mammalian predators preying on murrelet eggs was also present. A long-term monitoring, research, and restoration program is needed at Catalina. Initial restoration efforts should focus on reducing predation by introduced mammals and reducing impacts from oil pollution and bright lights.

RESUMEN.—Durante mucho tiempo (por lo menos varios milenios), la población pequeña de *Synthliboramphus scrippsi* en la Isla Santa Catalina, California, se limitó a parejas aisladas que anidaban en acantilados y costas, a los cuales, el zorro (*Urocyon littoralis catalinae*) no tiene acceso. Antes del año 1994, el único indicio de la existencia de *S. scrippsi* en Catalina era un nido que se encontró en Bird Rock en el año 1967. Entre los años 1994 y 1995, se observó una población más numerosa y más extensa, que se estima es de entre 25 y 75 parejas, gracias a investigaciones basadas en la detección vocal de estas aves que se encontraban en congregaciones nocturnas en el mar, en aguas cercanas a la orilla, próximas a las áreas de reproducción. Se escucharon individuos de *S. scrippsi* en 11 de 25 estaciones de investigación, y se registró la máxima actividad vocal entre Land's End y Ribbon Rock (estudio de 6 a 62 inspecciones-1). En el año 2004 y el año 2012, los conteos nocturnos en toda la isla analizaron mejor la distribución y la abundancia de las aves en las congregaciones, constituidas por 101 y 291 individuos, respectivamente, que se observaron a lo largo de un transecto de 82 km. El aumento de la cantidad en el año 2012 sugirió una población reproductiva actual de aproximadamente 100 y 200 parejas en Catalina, la cuarta colonia más grande del sur de California. Las congregaciones se asociaron ampliamente con acantilados costeros entre: (1) Isthmus Cove y Twin Rocks; y (2) Iron Bound Bay y Catalina Harbor. Las capturas nocturnas de 79 aves en congregaciones entre el año 2000 y el año 2013 registraron 10 (13%) de aves con parches de incubación, que habitualmente indican la puesta de huevos. Se observaron tres grupos familiares (adultos con pequeños polluelos con plumón) que partían de los nidos de la isla, en las aguas cercanas a la orilla durante las capturas en el año 2008, y en los conteos nocturnos en el año 2012. No se encontraron nidos durante las búsquedas en las rocas en el agua (incluyendo Bird Rock) entre 1991 y 1996, no obstante se encontraron siete nidos entre 2012 y 2013 durante las búsquedas en acantilados en la costa, a los que se pudo llegar en barco, entre Isthmus Cove y Twin Rocks. En total, seis de ocho puestas de huevos (75%) con destino conocido dieron buen resultado, pero encontramos indicios de mamíferos depredadores que cazaban huevos. Es necesario implementar un programa de monitoreo, investigación y restauración a largo plazo en Catalina. Los trabajos iniciales de restauración se deberán dedicar a reducir la depredación por mamíferos que se introducen en el hábitat y reducir el impacto de la contaminación por derrame de petróleo y la iluminación intensa.

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The population of Scripps's Murrelet (*Synthliboramphus scrippsi*) at Santa Catalina Island (hereafter "Catalina"), California, has been among the most poorly studied of the 6 California Channel Islands where murrelet breeding has been documented (Drost and Lewis 1995, Burkett et al. 2003). Breeding by Scripps's Murrelet in southern California was first documented at nearby Santa Barbara Island in 1863 (Carter et al. 2005), but little information was obtained concerning the presence or status of this seabird at Catalina through most of the 20th century. This lack was primarily due to the long-term presence (perhaps several millennia) of endemic island fox (*Urocyon littoralis catalinae*; Collins 1991), which has restricted the remnant murrelet population to isolated and undocumented nests in mostly inaccessible cliff and shoreline habitats. As a result, murrelets were not among the seabird species listed as present at Catalina in the early 20th century (Howell 1917). The first evidence of breeding at Catalina was not found until 1967 when naturalist D. Bleitz reported a single nest on Bird Rock near Two Harbors (Hunt et al. 1979, 1980). Until 1994, this discovery was the only evidence of murrelet breeding at the island. Major seabird colony surveys in the Channel Islands by the University of California, Irvine, in 1975–1977 (Hunt et al. 1979, 1980) and Humboldt State University (HSU) in 1991 (Carter et al. 1992) did not uncover any further evidence of murrelet breeding during very limited nest searches at Catalina, although these efforts occurred before effective at-sea congregation survey techniques had been developed.

Like other *Synthliboramphus* murrelets, Scripps's Murrelets attend congregations at night in nearshore waters adjacent to breeding areas (hereafter "congregations"; Murray et al. 1983, Whitworth et al. 1997, 2000), a conspicuous behavior that facilitates colony detection and population monitoring (Whitworth and Carter 2012, 2014). In 1994, HSU initiated nocturnal surveys of Scripps's Murrelets in congregations by using a vocal detection survey modified from a technique developed in 1987 to detect Marbled Murrelets (*Brachyramphus marmoratus*) in old-growth forests (Paton et al. 1990). HSU conducted vocal detection surveys to determine the distribution of Scripps's Murrelet breeding areas around all the California Channel Islands in 1994–1997 (including

Catalina in 1994–1995) and the Coronado Islands, Baja California, Mexico, in 1995 (H. Carter unpublished data). Similar surveys were conducted at other northwestern Baja California islands in 1999 (Keitt 2005). These surveys indicated that Scripps's Murrelets were more widespread in the Channel Islands than previously known (Burkett et al. 2003), but breeding areas were apparently limited at most islands to habitats inaccessible to fox, cats, and rats. However, it was difficult to estimate murrelet population size at an island from vocal detection survey data because (1) it was not possible to reliably correlate vocal activity with the actual number of murrelets present in the congregation; (2) widely spaced survey stations left large gaps in survey coverage; and (3) single surveys at most stations did not adequately examine the temporal variation in vocal activity.

Given their small world population size (7000–8000 breeding pairs; Karnovsky et al. 2005), restricted breeding range (Drost and Lewis 1995), limited number of breeding locations (at most 12 islands; Birt et al. 2012), and status as a threatened species in California (Burkett et al. 2003), development of a better population monitoring technique was critical to the conservation efforts for this species at Catalina and other islands. In 2001, the California Institute of Environmental Studies (CIES) and HSU developed a nocturnal spotlight survey technique (Whitworth and Carter 2012, 2014) for counting Scripps's Murrelets attending congregations. This survey technique can be used to (1) provide detailed information on the nesting distribution around islands, (2) refine estimates of population size, and (3) conduct long-term monitoring. Since 2004, CIES has conducted spotlight surveys at all known or suspected Scripps's Murrelet breeding islands throughout southern California (including Catalina in 2004) and northwestern Baja California. In 2012–2013, CIES and the Catalina Island Conservancy (CIC) began a multiyear study at Catalina to develop baseline data for assessing long-term Scripps's Murrelet population trends, using spotlight surveys, at-sea captures (Whitworth et al. 1997), and nest searches. In this paper, we provide the first detailed assessment of the status and distribution of Scripps's Murrelets at Catalina, based primarily on surveys conducted by HSU, CIES, and CIC between 1994 and 2013. In addition, we have conducted a preliminary

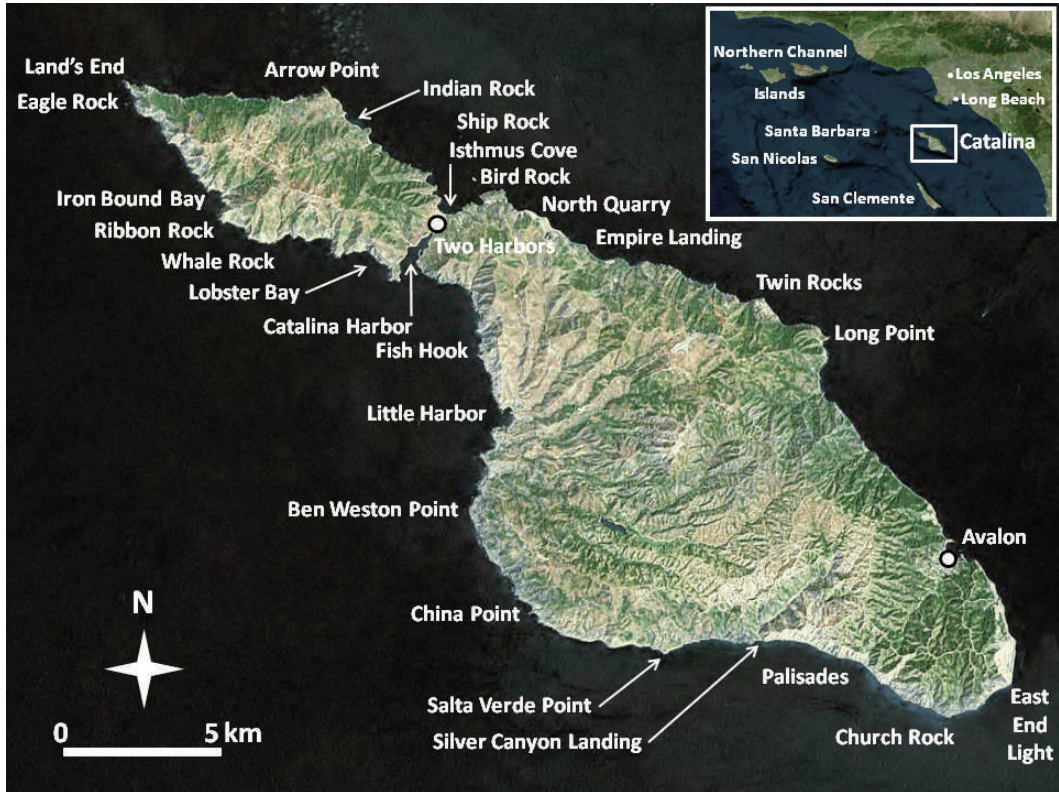


Fig. 1. Santa Catalina Island (33°24' N, 118°27' W), California, with place names mentioned in the text.

assessment of the conservation issues that may impact murrelets at Catalina and possible restoration options to benefit this small, vulnerable population.

METHODS

Study Area

Santa Catalina Island (33°24' N, 118°27' W) is located off the southern California coast near Los Angeles, about 30 km southwest of the Palos Verdes peninsula and the major international shipping port of Long Beach (Fig. 1). Catalina is the third largest (194 km²) of the 8 southern California Channel Islands and the largest of the 4 southern islands. Unlike the other Channel Islands, Catalina is not owned by the federal government; most of the island (88%) is owned by CIC, and the remainder is owned by the Santa Catalina Island Company (SCIC; 11%) and private entities (<1%) within the city of Avalon and on Bird Rock. As a result, Catalina has experienced more extensive

development than the other Channel Islands. A sizable human population (~4500) inhabits Catalina year-round, largely concentrated in the towns of Avalon and Two Harbors (Fig. 1), and is supplemented by over 800,000 tourists annually, mainly in the summer and autumn. Visitors also frequent 9 remote, boat-accessible shoreline campsites, 12 developed camps and yacht clubs, and over 1000 moorings that are present at nearly every cove or beach along the east (leeward) side of the island. However, many parts of the island remain undeveloped, especially west of the isthmus.

Introduced mammalian predators are abundant on the main island, including feral cats (*Felis catus*), black rats (*Rattus rattus*) and Norway rats (*Rattus norvegicus*), and house mice (*Mus musculus*; McChesney and Tershy 1998, CIC unpublished data). Catalina is also unique among the Channel Islands for having the highest diversity of potential native terrestrial predators: Santa Catalina Island fox, Santa Catalina Island deer mouse (*Peromyscus*



Fig. 2. Number of vocal detections of Scripps's Murrelets recorded at 25 at-sea stations at Santa Catalina Island, California, in 1994 and 1995. Solid white circles are scaled to the number of detections recorded at each station (range 0–62 detections per 15-min survey).

maniculatus catalinae), Santa Catalina Island harvest mouse (*Reithrodontomys megalotis catalinae*), Catalina California ground squirrel (*Otospermophilus beecheyi nesioticus*), Southern Pacific rattlesnake (*Crotalus oreganus helleri*), and San Diego gopher snake (*Pituophis catenifer annectens*).

Survey Techniques

VOCAL DETECTION SURVEYS.—Nocturnal vocal detection surveys were conducted to determine the distribution and relative levels of murrelet vocal activity at stations located 200–400 m from shore and spaced at intervals of 1–4 km around Catalina (Fig. 2). Each of the 25 stations was surveyed only once, with the exception of replicate surveys at Ship Rock and Arrow Point (one each in 1994 and 1995). Surveys were conducted as follows: 5 stations between Parson's Landing and Bird Rock on 13 May 1994 (21:33–23:32 PST); 9 stations between North Quarry and West Palisades, plus

Arrow Point and Ship Rock on 20–21 April 1995 (21:03–01:23); and 11 stations between Stony Point and Salta Verde Point on 17 May 1995 (00:20–03:49). In addition, hourly surveys were conducted from 20:00 to 23:00 to examine variation in vocal activity at Eagle Rock on 26 April 2000.

Each survey involved a primary observer in a drifting Zodiac inflatable craft counting all vocal detections heard over a 15-min period. A vocal detection was defined as a distinct call or series of calls separated by at least 3 s from the previous or succeeding call and originating from the same direction and relative distance. The data recorder entered the direction, distance, and minute of each detection on a data sheet and occasionally alerted the primary observer to calls that might have been missed. Detection direction was determined with reference to a compass, whereas distance was a subjective determination based on the amplitude of the call. We arrived at the survey

TABLE 1. Round-island spotlight surveys of Scripps's Murrelets conducted at Santa Catalina Island, California, in 2004 and 2012.

Year	Date	Time (PST)	Transect	Murrelets
2004	20–21 Apr	21:55–01:46	Arrow Point–East End Light	30
	2–3 May	21:51–01:46	Arrow Point–Ben Weston Point	60
	10–11 May	23:19–01:40	Ben Weston Point–East End Light	11
TOTAL				101
2012	22–23 Apr	22:22–00:51	Isthmus Cove–Catalina Harbor	86
	23–24 Apr	22:27–01:12	Catalina Harbor–Avalon	57
	24–25 Apr	22:14–00:28	Avalon–Isthmus Cove	148
TOTAL				291

TABLE 2. Standard spotlight surveys of Scripps's Murrelets conducted between Isthmus Cove and Twin Rocks at Santa Catalina Island, California, in 2012 and 2013.

Year	Date	Time (PST)	Isthmus Cove	Twin Rocks	Total
2012	24–25 Apr	23:27–00:28	46	86	132
	26–27 Apr	23:13–00:04	39	41	80
	27 Apr	23:05–00:00	41	43	84
	29 Apr	00:11–01:06	25	41	66
2013	15 Apr	21:32–22:28	29	74	103
	17 Apr	21:07–22:10	14	56	70
	17–18 Apr	23:51–00:53	33	41	74
	18 Apr	21:18–22:14	10	31	41
	19 May	22:12–23:11	2	0	2

TABLE 3. Scripps's Murrelet night-lighting captures conducted at Santa Catalina Island, California, 2000–2013.

Year	Night	Time (PST)	Murrelets captured	Brood patches (%)
2000	26–27 Apr	22:48–01:27	12	0
2004	3 May	02:56–03:21	2	0
	10 May	22:11–22:58	3	1 (33%)
2008	27–28 Apr	21:45–02:50	12	5 (42%)
2012	23 Apr	01:05–02:08	5	2 (40%)
	27 Apr	00:25–02:35	5 ^a	0
	28 Apr	00:15–02:44	11	0
	29 Apr	01:25–03:28	10	0
2013	15–16 Apr	22:42–02:35	15	2 (13%)
	18–19 Apr	23:29–00:37	3	0
	19–20 May	23:20–00:25	1	0

^aOne murrelet was not banded.

station at slow speeds in full darkness, turned off the outboard engine, and waited ≥ 2 min after arrival to allow murrelets to resume vocalizing before beginning a survey. Before each survey, environmental conditions were recorded as excellent, good, fair, or poor. Surveys were not conducted when winds exceeded approximately $20 \text{ km} \cdot \text{h}^{-1}$.

SPOTLIGHT SURVEYS.—Nocturnal spotlight surveys (Whitworth and Carter 2012, 2014) were conducted over 4 nights in 2004, 6 nights in 2012, and 4 nights in 2013 (Tables 1, 2). Round-island surveys circumnavigating Catalina at 200–300 m from shore were conducted in

2004 and 2012 and required 3 nights to complete (Table 1). The same 82-km transect was used in 2004 and 2012, although for logistic reasons (i.e., departure from different harbors or anchorages) the partial transects differed each year (Table 1). A “standard” transect (~ 10 km) covering dense congregations on the leeward shore between Isthmus Cove and Twin Rocks (Fig. 1) was established in 2012 to examine variation in murrelet attendance. Replicate standard surveys were conducted on 3 nights in 2012 and 4 nights in 2013 (Table 2).

AT-SEA CAPTURES.—Murrelets were captured using the night-lighting technique (Whitworth

et al. 1997) on 1 night in 2000, 2 nights in 2004, 1 night in 2008, 4 nights in 2012, and 3 nights in 2013 (Table 3). Capture efforts in 2000–2008 were conducted between Catalina Harbor and Eagle Rock; but in 2012–2013, captures were conducted mainly between Isthmus Cove and Twin Rocks, with only a few off Catalina Harbor in 2012. On nights when spotlight surveys and night-lighting captures were conducted in the same area, spotlight surveys were conducted first to avoid disrupting murrelets and affecting counts.

Each captured bird was (1) banded with a U.S. Geological Survey #2 stainless steel leg band; (2) identified to species by facial plumage (Jehl and Bond 1975); and (3) examined for presence and development of bilateral brood patches (scored after Sealy 1974) to assess probable breeding status. In 2008, blood samples were also collected for genetic analyses (Birt et al. 2012). Murrelets were held for 5–10 min and released immediately after processing.

NEST SEARCHES.—Small handheld flashlights were used to search suitable crevices and other sheltered sites for evidence of past or current breeding (e.g., incubating or brooding adult; whole, unattended eggs; broken or hatched eggshell fragments; eggshell membranes; or chicks; Whitworth et al. 2005, 2013). All nest search areas were accessed by an inflatable boat.

Nest searches by HSU were conducted on 31 May 1991, 13 May 1994, 20 April 1995, and 7 May 1996 (Carter et al. 1992; H. Carter unpublished data). Boat-accessible shoreline areas and offshore rocks were searched as follows: Bird Rock in 1991, 1994, 1995, and 1996; Ship Rock in 1991, 1994, and 1995; small offshore rocks and adjacent main island shoreline at Silver Canyon Landing in 1991 and 1996; Church Rock and adjacent main island shoreline in 1996; and selected shoreline habitats from Lobster Bay to Eagle Rock in 1996. Ship Rock also was searched by CIES on 28 April 2008.

Nest searches by CIES/CIC were conducted on 25 and 28 April 2012, 18 April 2013, and 20–22 May 2013. Boat-accessible shoreline areas and small offshore rocks were searched as follows: offshore rocks and main island between Empire Landing and Twin Rocks in April 2012 and April and May 2013; offshore rocks and main island between Two Harbors and Indian Rock in April 2012; main island between Isthmus Cove and Empire

Landing in May 2013; and main island between Isthmus Cove and Two Harbors in May 2013.

RESULTS

Vocal Detection Surveys

We found that overall vocal activity at Catalina in 1994–1995 was relatively low (6 ± 14 detections per survey; $n = 25$), quite variable (range 0–62 detections per survey; CV = 2.27), and localized (Fig. 2). Highest detections were recorded off the northwest coast at Land's End (62), Iron Bound Bay (34), and Ribbon Rock (20). Low vocal activity (≤ 10 detections) was recorded at 7 stations off the west coast of Catalina, and no detections were heard at 14 stations, mainly off the leeward shore (Fig. 2). On the leeward side of Catalina, the only station with detections was near the North Quarry (3). Detections were not recorded at Ship Rock and Arrow Point in 1994 or 1995. Four surveys near Eagle Rock in 2000 recorded 0–3 detections per survey. Conditions were excellent or good for most (71%) surveys, although windy conditions may have affected results during surveys at Arrow Point, Ship Rock, North Quarry, and Long Point on the night of 20–21 April 1995 (Fig. 2).

Spotlight Surveys

Round-island spotlight counts totaled 101 murrelets in 2004 and 291 murrelets in 2012 (Table 1). Three discrete areas accounted for most birds observed in both 2004 (72%) and 2012 (77%): (1) the northwest coast from Iron Bound Bay to just south of Catalina Harbor (hereafter “Northwest” congregation); (2) the leeward shore between Isthmus Cove and North Quarry (hereafter “Isthmus Cove” congregation); and (3) the leeward shore between Empire Landing and Twin Rocks (hereafter “Twin Rocks” congregation; Fig. 3). However, the proportion of birds counted in each area differed each year. In 2004, half (50%) were observed in the Northwest congregation and about a quarter (23%) in the Isthmus Cove–Twin Rocks congregations; but in 2012, about half (46%) were observed in the Isthmus Cove–Twin Rocks congregations and just a third (31%) in the Northwest congregation. Steep cliffs and slopes, often with rocky scree at the base, characterized shoreline habitats adjacent to congregations.

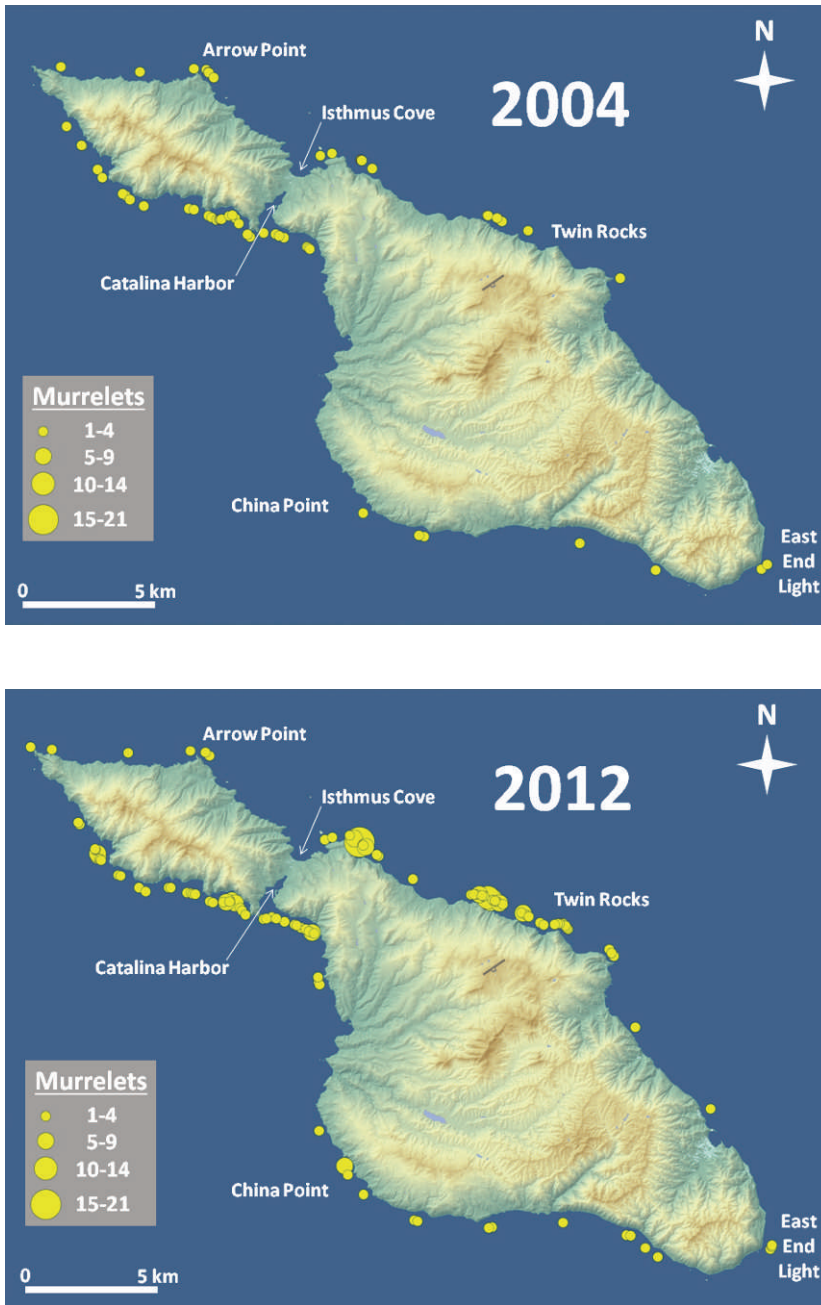


Fig. 3. Distribution and number of Scripps's Murrelets observed per scan during round-island nocturnal spotlight surveys at Santa Catalina Island, California, in 2004 (top) and 2012 (bottom).

Smaller congregations and isolated individuals or pairs were observed around the remainder of Catalina in 2004 and 2012, mainly on the south shore from East End to China Point and on the north shore from Iron Bound

Bay to Arrow Point. In almost all cases, murrelet observations were associated with isolated breeding habitat characterized by steep coastal cliffs (e.g., Arrow Point, Fish Hook; Fig. 4). One family

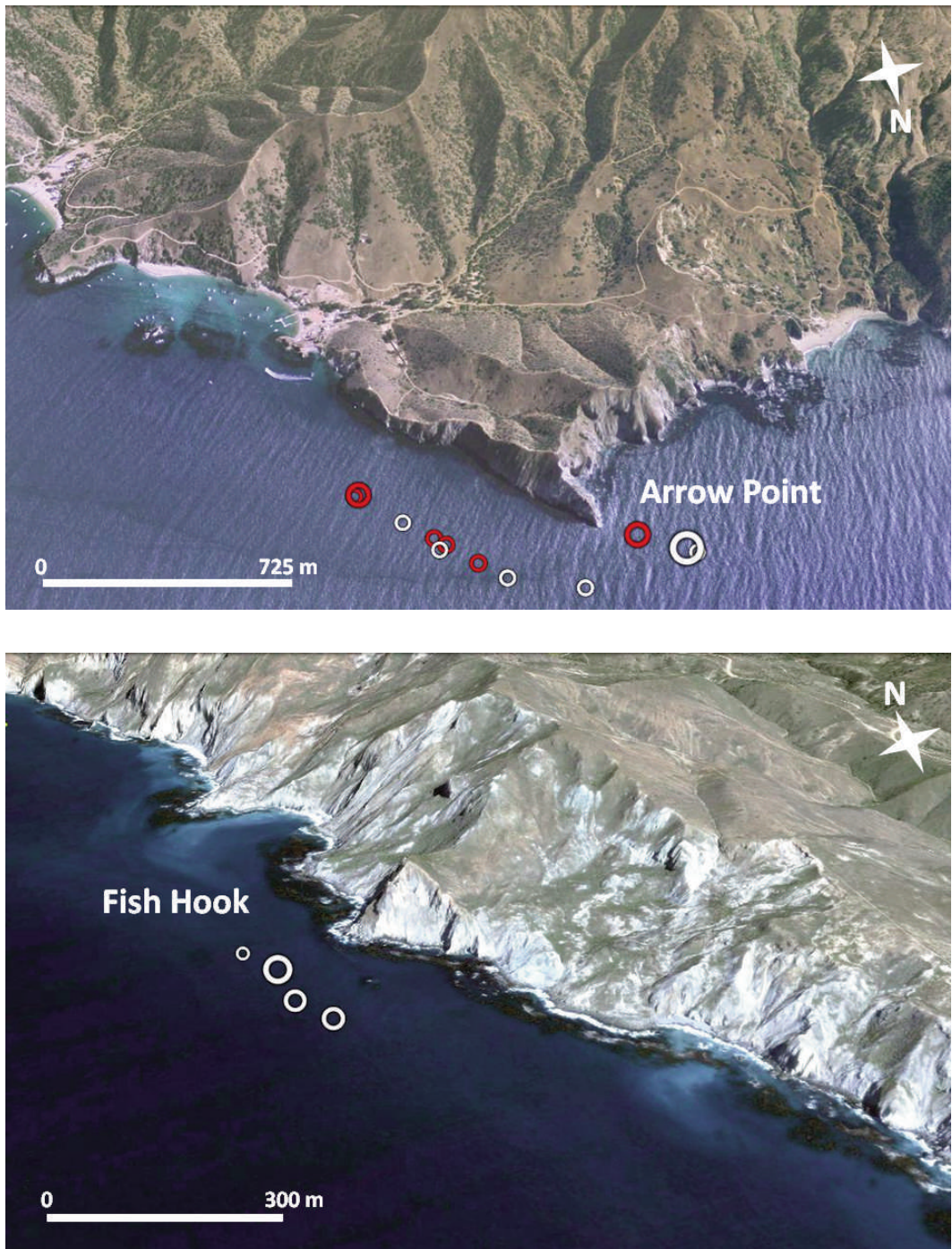


Fig. 4. Patchy cliff habitats at Santa Catalina Island, California, associated with small and isolated Scripps's Murrelet congregations near Arrow Point (top panel) and Fish Hook (bottom panel). Open circles are scaled to represent the number of murrelets per scan (smallest = 1; largest = 4) observed during round-island spotlight surveys in 2004 (red) and 2012 (white).

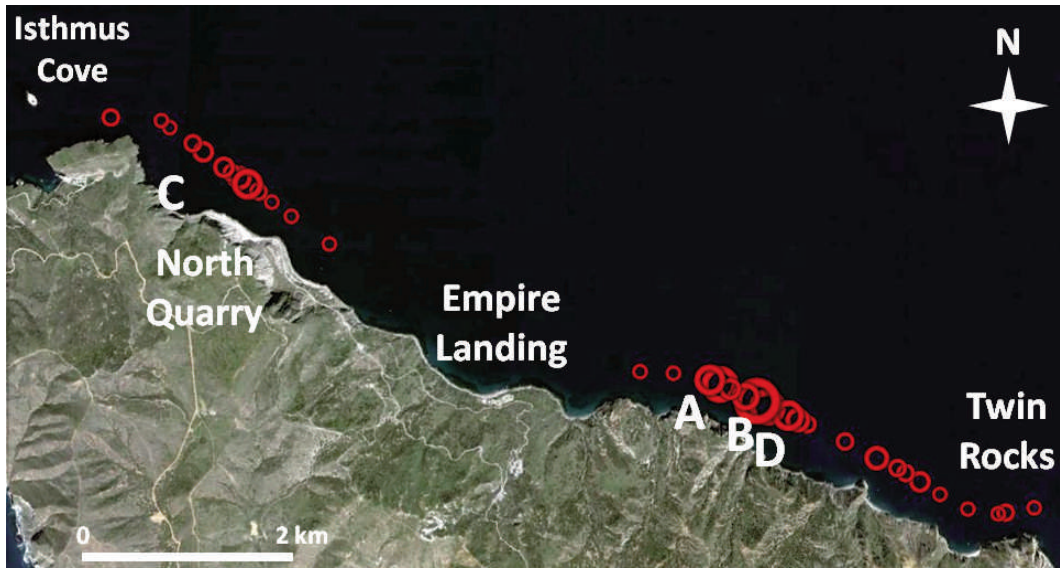


Fig. 5. Locations of Scripps's Murrelet nesting areas A–D between Isthmus Cove and Twin Rocks at Santa Catalina Island, California, in 2012–2013. Open red circles are scaled to represent the number of murrelets per scan (smallest = 1; largest = 11) observed during the standard spotlight survey on 15 April 2013.

TABLE 4. Scripps's Murrelet nests found at Santa Catalina Island, California, in 2012–2013. See Fig. 5 for location of nesting areas.

Nest number	Area	Nest contents	
		2012	2013
1	A	hatched egg	empty
2	A	depredated egg	empty
3	B	incubating adult	1 unhatched ^a and 1 hatched egg ^b
4	B	hatched egg	cracked egg ^a
5	C	not found	1 hatched and 1 depredated egg ^b
6	B	not found	hatched egg ^b
7	D	not found	hatched egg ^b

^aFound about 0.5 m below nest in April 2013.

^bMay 2013.

group (2 adults and a single small downy chick) was observed departing the island near China Point at 23:18 on 23 April 2012.

Standard spotlight counts ranged from 66 to 132 murrelets ($\bar{x} = 91 \pm 29$ murrelets) in April 2012 and from 41 to 103 murrelets ($\bar{x} = 72 \pm 25$ murrelets) in April 2013 (Table 2). Variation in April spotlight counts was similar both years, with CVs of 0.32 in 2012 and 0.35 in 2013. Counts generally decreased each night in both years, although slight increases were noted on consecutive nights in 2012 (26 and 27 April) and during 2 surveys on 17 April 2013 (Table 2). Only 2 murrelets were counted during the lone standard survey in May 2013

(Table 2). Counts were consistently higher in the Twin Rocks congregation (52 ± 19 murrelets; range 31–86) compared to Isthmus Cove congregation (30 ± 13 murrelets; range 10–46; Table 2).

Results of suspended or supplemental spotlight surveys include 8 murrelets observed between Land's End and Whale Rock (7.3 km) from 22:03 to 23:07 on 19 April 2004; 8 murrelets observed between Isthmus Cove and west of Arrow Point (~6 km) from 23:01 to 23:42 on 28 April 2012; and 1 murrelet observed on a transect (<1 km) around Ship Rock from 23:21 to 23:32 on 17 April 2013. These surveys confirm the data obtained on

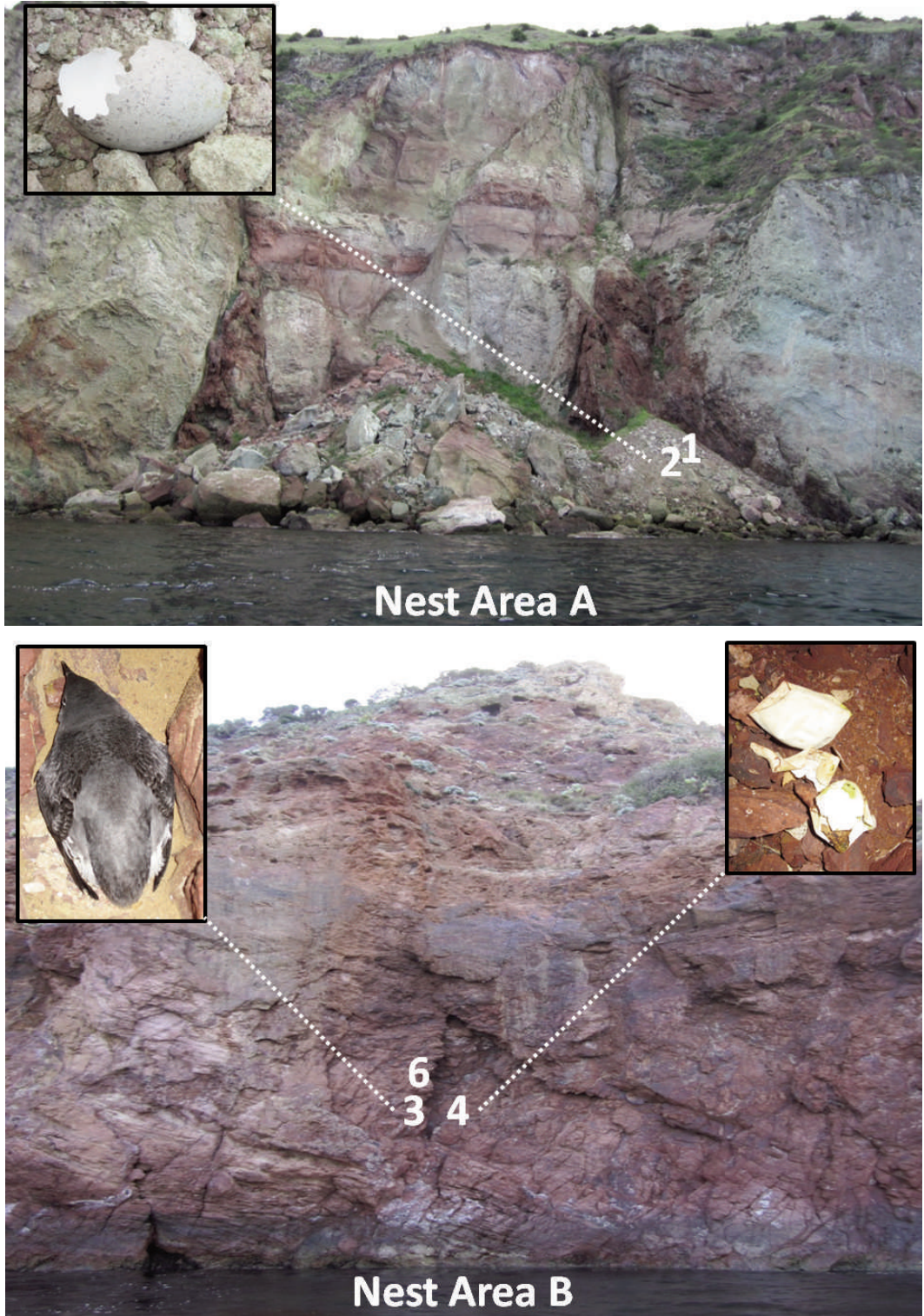
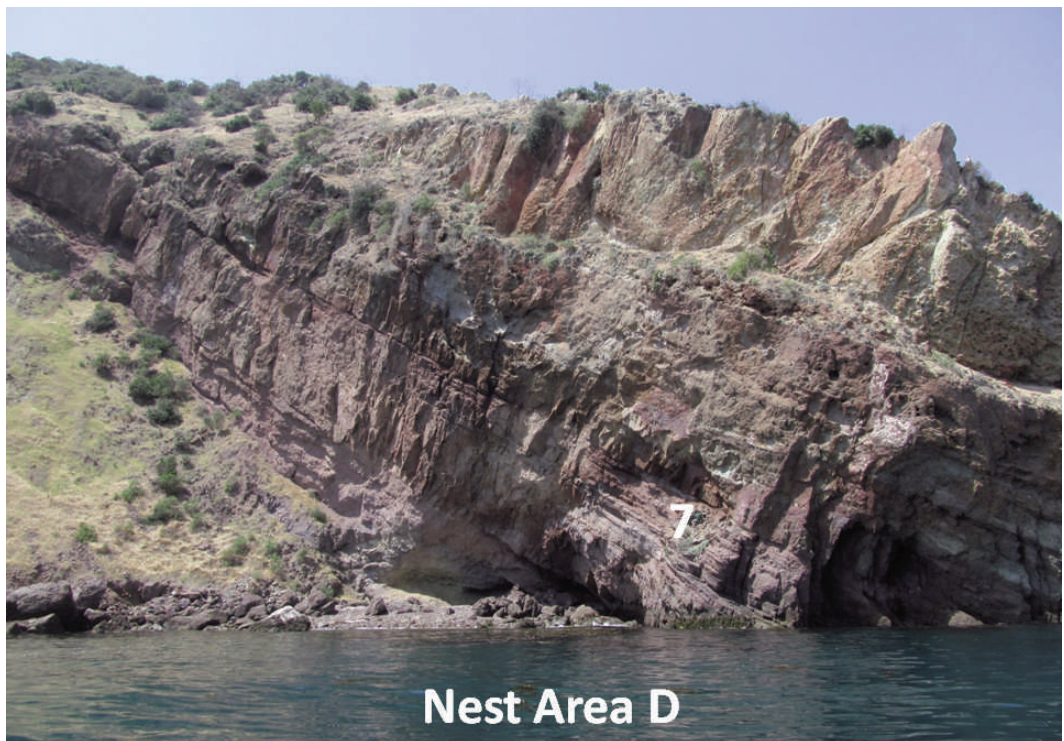
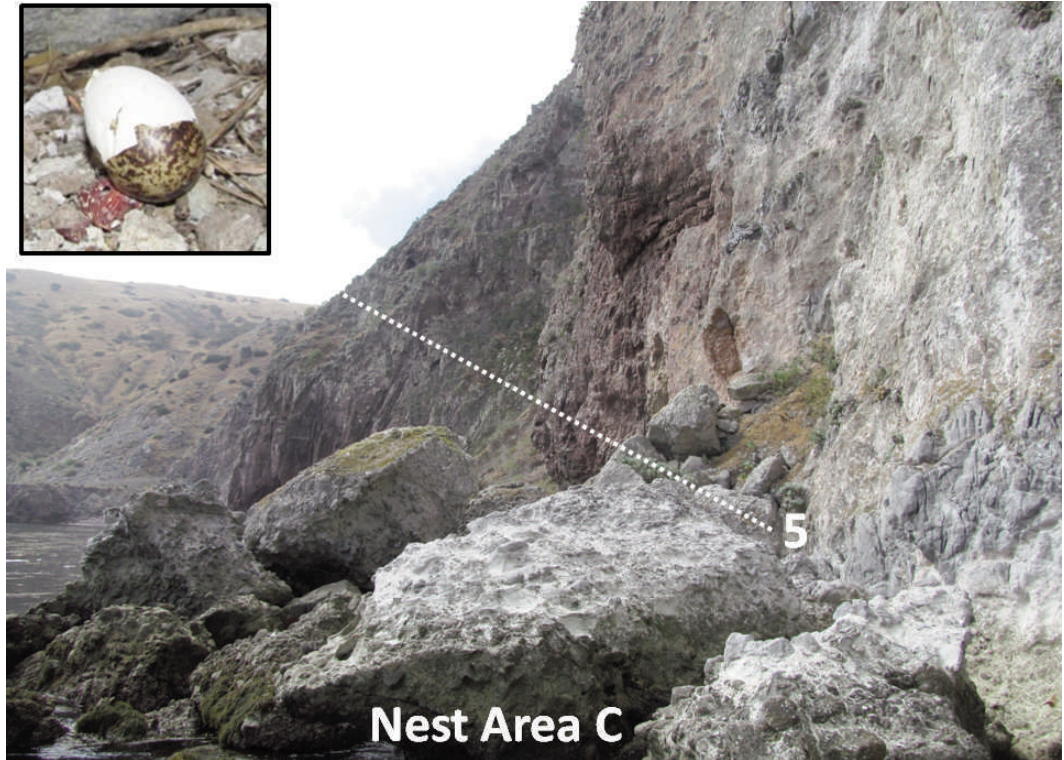


Fig. 6. Scripps's Murrelet nesting areas A–D between Isthmus Cove and Twin Rocks at Santa Catalina Island, California, (nest 2), an incubating adult (nest 3), and hatched eggs (nests 4–5).



in 2012–2013. Numbers indicate nest locations in each area (see Table 4). Inset photos depict a rodent-depredated egg

round-island surveys and suggest possible nesting at Ship Rock in 2013.

At-Sea Captures

We captured 79 Scripps's Murrelets at Catalina from 2000 to 2013 (Table 3). Ten murrelets (13%) had well-developed brood patches, although the annual proportion of murrelets with brood patches ranged from 0% to 42%. No murrelets were recaptured, but insufficient capture effort has been expended to date. During captures on 27–28 April 2008, family groups were observed in nearshore waters in Iron Bound Bay (1 adult and 1 small downy chick between 00:00 and 00:30) and Lobster Bay (2 adults and 2 small downy chicks between 00:45 and 01:25).

Nest Searches

No Scripps's Murrelet nests were found during searches in 1991–1996 or 2008. Despite the nest record from 1967 (Hunt et al. 1979, 1980), crevices large enough for breeding were not found on Bird Rock. Potential nest crevices were not found on Church Rock either, but were noted at Ship Rock ($n = 15$ – 20) and Silver Canyon Landing ($n = 4$) and shoreline areas near Church Rock ($n > 10$). Many crevices were also found on the shoreline between Lobster Bay and Eagle Rock.

A total of 7 murrelet nests were found in 4 discrete, boat-accessible areas between Isthmus Cove and Twin Rocks in 2012–2013 (Table 4; Figs. 5, 6). All nests were found either in rocky scree at the base of sheer coastal cliffs or on narrow ledges or fissures on the face of otherwise sheer cliffs (Fig. 6). All 4 documented nesting areas were found in coastal habitats adjacent to congregations (Fig. 5).

A total of 9 clutches were recorded in 2012–2013 (Table 4). Only 2 of the 4 nests found in 2012 were also active in 2013. Overall, 6 of 8 clutches (75%) with known fates were successful (defined as at least one hatched egg per clutch; Whitworth et al. 2013). We did not determine the clutch fate for nest 3 where an incubating adult was observed in April 2012 (Fig. 6). Failed clutches were recorded in nest 2 in 2012 (apparently a rodent-depredated or scavenged egg; Fig. 6 inset) and nest 4 in 2013 (a cracked egg found about 0.5 m below the nest).

DISCUSSION

Population Size and Trends at Catalina

Since 1994, greatly improved knowledge of the distribution and abundance of Scripps's Murrelets at breeding islands has been gathered through the use of congregation surveys, particularly at islands such as Catalina where native and introduced mammalian predators have severely limited the nesting habitats available to murrelets. Prior to these studies, the murrelet population at Catalina was considered negligible. After unsuccessful nest searches limited to Bird Rock in 1976–1977, Hunt et al. (1979) stated that “if murrelets bred there at all, their nests sites were few and scattered far apart.” Similarly, Carter et al. (1992) suspected “only small numbers” (<5–25 breeding pairs) after unsuccessful nest searches on Bird Rock, Ship Rock, and Silver Canyon Landing in 1991. Both assessments recognized the possibility of Scripps's murrelets breeding in the steep coastal habitats at Catalina, but given the limited information available at the time, the reports likely underestimated the size of the overall population. Based mainly on 1994–1995 vocal detection surveys around the entire island, HSU reported a significant breeding population of 25–75 pairs, mainly on the steep northwest coast between Land's End and Ribbon Rock (Burkett et al. 2003). This estimate was still considered adequate following the first spotlight surveys at Catalina in 2004 (101 birds), but the counts in 2004 were affected by late and reduced breeding that probably resulted in decreased congregation attendance. Compared to counts at Santa Barbara Island, the round-island spotlight count at Catalina in 2012 (291 murrelets) suggests a larger population of roughly 100–200 breeding pairs, perhaps the fourth largest colony containing about 10% of the overall population of Scripps's Murrelets in the Channel Islands (D. Whitworth and H. Carter unpublished data). Differences in population assessments between 1967 and 2013 resulted mainly from greater survey effort and increasingly effective survey techniques rather than population increases over this period. Considering the limited breeding habitats available to murrelets at Catalina prior to other human impacts in the 19th and 20th centuries, we consider it highly unlikely that the historic population was much greater than what was found in 2012–2013.

Though data are insufficient to reliably determine past population trends, spotlight surveys in 2012–2013 now provide baseline data for long-term trend monitoring. The variation evident in standard spotlight counts reflects various behavioral and environmental factors that affect use of congregations by murrelets on specific nights (Whitworth et al. 2000). Annual variation at Catalina in 2012–2013 was generally consistent with that observed at Anacapa Island in 2001–2006, although more nights were surveyed at Anacapa Island in most years (Whitworth and Carter 2012, 2014). Given the annual variability in timing of breeding observed at Santa Barbara and Anacapa Islands (Drost and Lewis 1995, Whitworth and Carter 2014), larger samples of annual surveys (8–10 survey nights) at Catalina are desirable to help minimize variation and ensure that spotlight counts are conducted during peak congregation attendance. Larger samples would provide more reliable maximum and mean counts to better measure population trends. Logistic and financial constraints may preclude such large samples in certain years, but major population changes will still be detected with a minimum of 4–5 surveys per year.

The Isthmus Cove, Twin Rocks, and Northwest congregations accounted for roughly 75% of all murrelets counted at Catalina. Furthermore, these congregations were easily accessible from safe harbors and relatively protected from prevailing winds and swells, such that adequate numbers of replicate standard spotlight surveys could be used to monitor overall population trends at Catalina. Surveys on multiple standard transects are desirable at large islands like Catalina because the effects of mammalian predators and marine anthropogenic impacts (e.g., oil spills, bright lights) may vary. Round-island surveys should also be conducted periodically to detect major changes in other areas and confirm the relationship between standard surveys and the rest of the island. Positive correlations have been noted between standard and round-island counts at Anacapa Island (Whitworth and Carter 2012, 2014).

Isthmus Cove and Northwest congregations also are particularly suitable for capture efforts and mark-recapture analyses. Although Scripps's Murrelets were not recaptured in 2012 or 2013, continued at-sea captures over several

consecutive years should provide reasonable recapture rates (as at Anacapa and Santa Barbara islands; D. Whitworth and H. Carter unpublished data) that permit Jolly–Seber population estimates (Jolly 1965, Seber 1965). Jolly–Seber population estimates can be compared to population estimates derived from spotlight survey data and can help validate these estimates or reveal potential biases in spotlight or capture data and analyses. Recaptures of banded murrelets at Catalina and other nearby islands also may provide information on nesting area fidelity, longevity, and mortality at or away from Catalina and possible movements between breeding islands (not yet detected in the Channel Islands; D. Whitworth and H. Carter unpublished data).

Nest Searches and Monitoring

Obtaining an adequate sample of monitored nests to determine hatching success and to assess reasons for clutch failures (e.g., Whitworth et al. 2005, 2013) is another important step in protecting and restoring Scripps's Murrelets at Catalina. Under typical weather conditions, nest searches and monitoring can be conducted every 10–14 days on the protected and easily accessible shorelines adjacent to the Isthmus Cove and Twin Rocks congregations, and possibly east of Whale Rock near the Northwest congregation. This interval between nest checks is efficient for monitoring at islands such as Catalina, as it allows for reliable estimation of hatching success and timing of breeding and reasonable detection of clutches depredated soon after egg laying (Whitworth et al. 2013).

Monitoring a sample of nests in different habitats and areas at Catalina will help determine impacts of predation, but sample sizes may be relatively low (5–10 nests per year). At-sea locations of murrelets in the Isthmus Cove and Twin Rocks congregations helped us target shoreline nest searches, leading to discovery of 7 nests in 2012–2013; but limited time and adverse conditions prevented nest searches on the northwest coast in both years. No nests but many potential crevices were found in 1996 during brief searches on the northwest coast between Land's End and Catalina Harbor. However, observations strongly indicative of murrelet nesting have been consistently noted off the northwest coast, including

(1) high levels of vocal activity in 1994; (2) ornithological radar detections of murrelets flying in and out of cliffs along a 1.6-km section of the coast just south of Eagle Rock in 2000 (Hamer et al. 2005); (3) relatively high spotlight counts in 2004 and 2012; and (4) two family groups noted just off Iron Bound Bay and Lobster Bay during at-sea captures in 2008. Periodic nest searches will be desirable in additional areas, but it seems unlikely that regular nest monitoring can be conducted on the exposed north coastline between Whale Rock and Arrow Point or on the more remote south end of the island from China Point to East End. Isolated congregations occur in these areas, but nests have yet to be discovered on the adjacent shoreline.

The lack of suitable nest sites on Bird Rock in 1991–1996 is puzzling, given the nest record from 1967 (Hunt et al. 1979). A few suitable nesting sites may have gone unnoticed in 1991–1996, perhaps hidden among the roots of the large *Opuntia* cactus patch on the rock, or crevices may have been destroyed by frequent human visitation (e.g., Hunt et al. 1979, Hand 1980). It is also possible that the site of the original 1967 nest record was mistakenly identified as Bird Rock (also known as “White Rock”; Doran 1980), when the nest was actually found on nearby Ship Rock where many suitable nest crevices occur.

Overall hatching success at Catalina in 2012–2013 was relatively high (75%), but we did find evidence of mammalian predators accessing current or potential murrelet nest sites and preying on murrelet eggs. Apparent (but not confirmed) rat feces were found in the rocky scree in nesting areas A and C, and a mummified fox carcass was found in a small shoreline cave where murrelet footprints were also observed. Reliably determining clutch fates was difficult with just one or two nest checks. Clutch fates for nests 3 and 4 in 2013 were particularly difficult to interpret. One hatched egg in nest 3 in May 2013 indicated successful nesting that year, although single eggs were found about 0.5 m below nests 3 and 4 in April 2013. Both eggs appeared to have rolled out of the nests, possibly related to competition for suitable crevices in the small fissure. Aggressive competition for nest sites resulting in egg damage and displacement has been observed recently at nearby Santa Barbara Island (L. Harvey personal communication).

Conservation and Restoration

MAMMALIAN PREDATORS.—The chief constraint limiting the breeding population of Scripps’s Murrelet at Catalina has probably been the accessibility of many coastal habitats to mammalian predators (Hunt et al. 1979, 1980). The Santa Catalina Island fox has been present on the island for perhaps 6 millennia and is currently abundant (1502 individuals island-wide in 2012; King et al. 2014) and present in almost all habitat types. Due to its current status as a federally endangered species and California state threatened species, control measures for foxes are not currently allowed.

Feral cats and rats were likely first introduced on Catalina in the early or mid-19th century by nonnative peoples visiting the island for ranching, mining, or hunting purposes. Further introductions probably occurred later in the 19th century as boat travel increased between Catalina and mainland ports. Feral cats are recognized predators of adult Scripps’s Murrelets, and rats prey on murrelet adults and eggs (McChesney and Tershy 1998, Nogales et al. 2004, Whitworth et al. 2005, Jones et al. 2008). Feral cats currently occur in highest densities in the towns of Avalon and Two Harbors, and they also are found near camps along the leeward side, where food-supplemented individuals range throughout the Catalina wildlands. The feral cat population was most recently estimated at 600–750 individuals (Guttilla and Stapp 2010). Rat densities are highest near areas of human habitation, but rats have also been detected in more remote areas. An annual CIC fox trapping effort using Tomahawk traps has captured rats at widespread locations (J. King unpublished data).

High priority has been given to eradicating introduced mammals on many murrelet breeding islands in southern California and Baja California (McChesney and Tershy 1998, Keitt 2005, Aguirre-Muñoz et al. 2008, Howald et al. 2009). Eradication of rats at Anacapa Island in 2001–2002 greatly improved murrelet hatching success in 2003–2010 (Whitworth et al. 2005, 2013), but eradication of cats and rats at Catalina is not currently feasible. The primary focus for restoration efforts in the near future at Catalina should be the local removal of introduced cats and rats from Scripps’s Murrelet breeding areas. This action would have immediate benefits and can be conducted largely by the CIC. The need to

avoid creating potential negative impacts on island fox would severely limit nonnative predator control measures, but exclusion fencing of small sections of shoreline with breeding murrelets may be possible. More work is needed to (1) identify nesting habitats being used by murrelets; (2) consider types, costs, and efficacy of fencing; and (3) gather baseline monitoring data on murrelet nests to document current impacts by introduced mammals and demonstrate improved breeding after local removals.

The endemic Santa Catalina Island deer mouse is abundant and widespread. Deer mice are known predators and scavengers of murrelet eggs at Santa Barbara Island and Anacapa Island (Schwemm and Martin 2005). Scavenging of unviable abandoned eggs by deer mice can be difficult to separate from egg predation, which typically occurs when viable eggs are left unattended by adults (Drost and Lewis 1995, Schwemm and Martin 2005, Whitworth et al. 2013).

OIL POLLUTION.—The potential impacts of large and small oil spills in congregation waters near murrelet breeding islands is of great concern (Carter et al. 2000, Burkett et al. 2003). Long Beach Harbor is the largest oil port in western North America, with daily arrivals and departures of large oil tankers (USFWS 2005). Frequent oil spills occur in the vicinity of Long Beach Harbor, but most have not affected waters near Catalina (Carter 2003). Although general contingency plans for oil spills have been developed, a more detailed plan is needed for Catalina that would allow for effective training and coordination of pre-spill baseline, spill-response, and post-spill activities among the CIC, the SCIC, the city of Avalon, and federal and state wildlife and oil spill response agencies. Spill-response activities that would benefit Scripps's Murrelets at Catalina include (1) recovering carcasses of dead murrelets; (2) capturing live oiled murrelets in congregations and immediately transporting them to existing facilities in the Long Beach area for cleaning and rehabilitation; (3) improving rehabilitation and captive housing techniques for murrelets in the Long Beach area; (4) conducting post-release studies to evaluate survival and breeding after rehabilitation; and (5) conducting spotlight surveys during and after the spill to assess changes in the numbers of murrelets attending congregations.

BRIGHT LIGHTS.—The potential impacts of bright lights near murrelet breeding colonies is another concern because such lights discourage congregation visitation and may result in nest abandonment, heightened predation, and collision mortalities (Carter et al. 2000, Burkett et al. 2003). Direct evidence of impacts from bright lights is not available, but many owl-depredated murrelets were found at Santa Barbara Island in 1999 during an unusual period of intense squid fishing with bright lights near the island (P. Martin unpublished data). Commercial squid fishing boats frequent Catalina waters and use very bright lights; but the number and distribution of these boats varies between years, and no information of their impact on murrelets at Catalina is available. During vocal detection surveys in 1994–1995, squid fishing occurred mainly in shallow waters off Salta Verde Point and the Palisades (Fig. 1). Squid fishing was not noted during spotlight surveys in 2004 but did occur in shallow waters off China Point and Ben Weston Point in 2012. More information is needed on all light sources, baseline light levels, and possible effects on murrelets around Catalina. Consultation and cooperation with the commercial squid fishing fleet may help avoid impacts from brightly lighted boats near shore (e.g., establishing voluntary buffer zones around major breeding and congregation areas during the murrelet breeding season).

ORGANOCHLORINE POLLUTION.—Extensive organochlorine pollution in the Southern California Bight greatly affected reproduction of Brown Pelicans (*Pelecanus occidentalis*) and Double-crested Cormorants (*Phalacrocorax auritus*), causing major population decline from the 1940s until the late 1970s (Gress et al. 1973, Gress 1995). The effects of potential pollutants on Scripps's Murrelets in the Channel Islands were not examined until 1992 when pollutant levels in eggs from Santa Barbara Island were found to be relatively low (U.S. Fish and Wildlife Service unpublished data). We do not consider organochlorine pollutants to be currently having a significant effect on murrelets breeding at Catalina; but past impacts may have caused reduced reproduction or lower population size, especially between the 1940s and 1970s, prior to the end of production and dumping of DDT in southern California waters.

AVIAN PREDATORS.—Bald Eagle (*Haliaeetus leucocephalus*), Peregrine Falcon (*Falco*

peregrinus), Barn Owl (*Tyto alba*), and Common Raven (*Corvus corax*) are the main avian predators at Catalina. After 2 decades of intensive restoration efforts by the Institute for Wildlife Studies (IWS), the reestablished Catalina population of Bald Eagles appears to be self-sustaining, although lingering impacts from organochlorine pollution still exist. In 2012, 6 nesting pairs and 7 active territories were documented at Catalina (Sharpe 2013). The degree of eagle predation on murrelets is not known, but a few murrelet remains have been recorded at eagle nests (IWS unpublished data). Breeding by Peregrine Falcons had not been recorded at Catalina in recent decades (like eagles, they were extirpated due to organochlorine pollution; Kiff 1980) until 2013 when a pair nested on an interior peak west of the isthmus (IWS unpublished data). Transients or nonbreeding resident falcons are present at Catalina year-round and likely prey on murrelets. The falcon nest at Catalina in 2013 was not successful, but if a breeding population is fully reestablished on Catalina in the future, predation on murrelets likely would increase. Extensive hacking efforts by the Predatory Bird Research Group at the University of California Santa Cruz have been successful at other Channel Islands (B. Latta unpublished data). Scripps's Murrelet constituted 5% of the total biomass in peregrine falcon prey remains examined from breeding territories at San Miguel, Santa Rosa, Santa Cruz, Anacapa, and Santa Barbara Islands in 2007 (B. Latta unpublished data). Barn Owls have been observed in low numbers year-round at widespread locations on Catalina (CIC unpublished data). Barn Owl impacts on murrelets at Catalina are unknown, but they are a major predator at Santa Barbara Island (Drost and Lewis 1995). Continued efforts to document the distribution, abundance, and impacts of avian predators on Scripps's Murrelets at Catalina are needed to assess current predation levels. Efforts to reduce impacts from avian predators will not be considered unless new information indicates unusually high predation.

LOSS OF NESTING HABITAT.—Since the late 19th century, roughly 5% of the Catalina coastline has been altered by development and 2 major rock quarries, mainly on the leeward shore. Scripps's Murrelets currently attend a relatively dense congregation near the north quarry, but assessing possible impacts of mining

(or other developments) on murrelets is not possible because no data exist to indicate the extent of historical nesting anywhere at Catalina. More work is needed to (1) collate historical information on the amount and seriousness of potential habitat loss for later assessment and (2) investigate possible nesting in little-used quarries. Efforts to restore lost breeding habitats are not currently being considered.

ACKNOWLEDGMENTS

Scripps's Murrelet surveys at Santa Catalina Island in 2012–2013 were funded by the National Fish and Wildlife Foundation. In-kind support was provided by the U.S. Navy (Naval Air Station North Island), California Institute of Environmental Studies (CIES), Catalina Island Conservancy (CIC), and Carter Biological Consulting (CBC), with key assistance by F. Gress and M. Booker. Valuable field assistance was provided by D. Mahoney, C. Duncan, R. Haehn, T. Dowling, T. Summers, the American Conservation Experience, and the Wrigley Marine Sciences Center (University of Southern California).

Surveys by Humboldt State University (HSU) and CIES in 1991–2008 were funded by the U.S. Navy (Legacy Resource Management Program), California Department of Fish and Game, U.S. Fish and Wildlife Service, Minerals Management Service, American Trader Trustee Council, Chevron, and CIES, with key assistance from E. Burkett, F. Gress, T. Keeney, P. Kelly, G. Minnery, G. Reetz, and T. Zimmerman. In-kind support was provided by the U.S. Navy (Point Mugu Naval Air Weapons Station), Channel Islands National Marine Sanctuary, National Biological Service, U.S. Fish and Wildlife Service, U.S. Geological Survey, HSU, CIES, CIC, and CBC, with key assistance from S. Fangman, D. Gilmer, R. Golightly, F. Gress, T. Keeney, and D. Orthmeyer. Valuable vessel support was provided by Instinct Charters (F/V *Instinct*; D. Christy), Channel Islands National Marine Sanctuary (RV *Ballena* and *Shearwater*; S. Fangman), and Algalita Marine Research Foundation (ORV *Alquita*; C. Moore). Excellent field assistance was provided by B. Birmingham, J. Bulger, M. Gay, F. Gress, P. Hébert, J. Koepke, D. Lewis, G. McChesney, W. McIver, S. Newman, L. Ochikubo, M. Pierson, and R. Young.

We thank B. Coleman (CIC) for assistance with figures and 2 anonymous reviewers for their valuable comments to improve the manuscript.

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Received 23 April 2013

Accepted 24 January 2014

Early online 5 December 2014