AT-SEA CONGREGATION SURVEYS TO ASSESS THE STATUS OF SCRIPPS'S MURRELETS *SYNTHLIBORAMPHUS SCRIPPSI* AT ISLANDS OFF WESTERN BAJA CALIFORNIA, MEXICO IN 2002–2008

DARRELL L. WHITWORTH[1*], HARRY R. CARTER[1,2,†], EDUARDO PALACIOS[1,3] & FRANKLIN GRESS[1]

[1]*California Institute of Environmental Studies, P.O. Box 1185, Davis, California 95617, USA* [*]*(darrellwhitworth@ciesresearch.com)*
[2]*Carter Biological Consulting, 1015 Hampshire Road, Victoria, British Columbia V8S 4S8, Canada*
[3]*Centro de Investigación Científica y Educación Superior de Ensenada, Unidad La Paz, Miraflores 334 Col. Bellavista, La Paz, Baja California Sur 23050, Mexico*
[†]*Deceased*

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ABSTRACT

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In 2002–2008, we conducted spotlight surveys and at-sea captures to determine the distribution and estimate the population size of *Synthliboramphus* murrelets at nine islands off the Pacific coast of Baja California (BC), Mexico. Scripps's Murrelets *S. scrippsi* (SCMU) were detected in nocturnal at-sea congregations near six islands: Islas Coronado (IC), Todos Santos (TS), San Martin (SM), San Jeronimo (SJ), San Benito (SB), and Cedros (CD). Nest searches confirmed breeding at all islands except SM and CD, where breeding was presumed based on congregation attendance. Historically, SCMU were known or suspected to breed at all of these islands except CD, but knowledge of population size and trends prior to 1999 was limited to qualitative estimates and speculation. In 2002–2008, we estimated the total SCMU breeding population in the region to be 1686–4428 pairs, including 1117–2933 at IC, 262–688 at TS, 19–49 at SM, 24–64 at SJ, 231–607 at SB, and 33–87 at CD. SCMU populations have likely increased at IC, TS, SM, and SB since the eradication of cats in the late 1990s, but the small colony on SJ may be limited by competition for nest sites by a large and growing Cassin's Auklet *Ptychoramphus aleuticus* colony. Recent trends are unknown for the remnant SCMU population at CD, where breeding is restricted to isolated refuges safe from terrestrial predators. Although these surveys were conducted 11–17 years ago, these data provide the most recent population estimates available for these islands and offer a reliable modern baseline for measuring future population trends.

Key words: at-sea congregation, Baja California, Islas Coronado, San Benito, San Jeronimo, Todos Santos, Scripps's Murrelet, spotlight surveys

INTRODUCTION

Three species of *Synthliboramphus* murrelets (Scripps's Murrelet *S. scrippsi* [SCMU], Guadalupe Murrelet *S. hypoleucus* [GUMU], and Craveri's Murrelet *S. craveri* [CRMU]) have been documented breeding on islands off the Pacific coast of Baja California (BC), Mexico (Jehl & Bond 1975, Drost & Lewis 1995, Keitt 2005, Whitworth *et al*. 2018a). However, since the first descriptions of these species in the mid-1800s (Carter *et al*. 2005), knowledge of their status and distribution in the region has been muddled. Most historical information regarding murrelets on the western BC islands was based on infrequent observations made by naturalists and egg/skin collectors (Jehl & Bond 1975). Determining the number, or even presence, of nesting murrelets is inherently difficult because all three species nest in concealed sites (i.e., rock crevices and dense shrubs) and are strictly nocturnal in their activities at the colony (DeWeese & Anderson 1976, Murray *et al*. 1983). Difficulties assessing the status of murrelets on BC islands were exacerbated by the introduction of cats *Felis catus,* which devastated populations throughout the region (McChesney & Tershy 1998, Keitt 2005). At some islands, remnant murrelet populations were restricted entirely to refuges in inaccessible habitats (e.g., cliffs, sea caves, and offshore rocks) to such an extent that colonies on Islas Todos Santos, San Jeronimo, and San Martin were presumed to have been extirpated (Jehl & Bond 1975). As late as the mid-1990s, the status of *Synthliboramphus* murrelet populations on some Pacific BC islands was still unknown (Drost & Lewis 1995).

All three murrelet species in Mexico are classified as endangered (SEMARNAT 2010) and warrant much more attention than they have received over the past few decades. Spotlight surveys (Whitworth & Carter 2014) and night-lighting captures (Whitworth *et al*. 1997) of murrelets in at-sea congregations adjacent to nesting areas have proven to be useful techniques for detecting colonies, determining species presence, and estimating population size and trends (e.g., Whitworth *et al*. 2014, 2018a, 2018b; Whitworth & Carter 2014, 2018a). During 2002–2008, we conducted the first spotlight surveys and at-sea captures at nine islands off western BC from Islas Coronado south to Asunción (Fig. 1). In a previous paper (Whitworth *et al*. 2018a), we presented the first convincing evidence that CRMU breed at four islands off west-central BC and discussed the distribution and size of these colonies. In this paper, we use the results of our 2002–2008 surveys to update the status and distribution of SCMU at Islas Coronado, Todos Santos, San Martin, San Jeronimo, San Benito, and Cedros. To emphasize the importance of standardized surveys in conservation efforts for *Synthliboramphus* murrelets, we also discuss the scant history

of murrelet breeding on these six islands based on a review of published literature and searches of museum records in the VertNet Portal (http://www.vertnet.org).

STUDY AREA

Islas Coronado (IC), Todos Santos (TS), San Martin (SM), San Jeronimo (SJ), San Benito (SB), and Cedros (CD) are continental islands located across a > 500 km expanse of the Pacific Ocean off the west coast of BC, between the US-Mexico border and Punta Eugenia (Fig. 1). These six islands include one large island (CD), three small island groups (IC, TS, SB), and two small islands (SM, SJ; Table 1, Figs. 2–7). Hereafter, the term "island" may refer to a single island or an island group, and the acronyms SB, TS, and IC will refer to all the islets of these groups collectively. The rocky coastal breeding habitats on these islands are vegetated predominately in Mediterranean coastal scrub (IC, TS, SM, parts of CD) or desert scrub (SB, SJ, parts of CD). All of these islands were incorporated in the Pacific Islands of Baja California Peninsula Biosphere Reserve in 2016 (DOF 2016), but each has a significant history of human disturbances that likely had (and may still have) detrimental effects on murrelet populations (Keitt 2005, Samaniego-Herrera *et al*. 2007). Feral cats and other non-native mammals have, in the past, been documented on all the islands (except IC Medio and Roca Media) and are still present on CD, but feral cats were eradicated on the other islands by 1999, as were all other non-native mammals by 2003 (McChesney & Tershy 1998, Keitt 2005). A species of deer mouse that is endemic to CD (*Peromyscus eremicus cedrocensis*) was introduced on SB Oeste in 2006 but was eradicated by 2013 (Samaniego-Herrera *et al.* 2007). These islands have experienced varying degrees of human development, mainly lighthouses and fishing villages, with CD being the most extensively developed (Table 1).

Fig. 1. *Synthliboramphus* murrelet breeding islands on the Pacific coast of Baja California, Mexico. Islands where Scripps's Murrelet is known or suspected to breed are underlined.

TABLE 1
Physical characteristics of Islas Coronado (IC), Todos Santos (TS), San Martin (SM), San Jeronimo (SJ), San Benito (SB), and Cedros (CD), off the Pacific coast of Baja California, Mexico.

Island	Islet	Latitude, Longitude	Area (km^2)	Elevation (m)	Population	Human use[a]
IC	Sur	32°24′N, 117°14′W	1.16	220	8	L, M, A
	Norte	32°26′N, 117°17′W	0.37	153	–	F[b]
	Medio	32°25′N, 117°15′W	0.09	33	–	–
	Roca Media	32°25′N, 117°15′W	0.02	32	–	–
TS	Sur	31°48′N, 116°47′W	0.89	95	6	F, L, A
	Norte	31°48′N, 116°48′W	0.32	17	–	L, M
SM	–	30°29′N, 116°06′W	2.68	144	–	F[c], L
SJ	–	29°47′N, 115°47′W	0.39	44	–	F[c], L, C[d]
SB	Oeste	28°18′N, 115°35′W	4.07	212	60	F, L, R
	Este	28°18′N, 115°32′W	1.56	128	–	–
	Medio	28°18′N, 115°34′W	0.54	25	–	R
CD	–	28°10′N 115°13′W	347.95	1204	4500	T, F, L, M, C[e]

[a] L = lighthouse; M = military; A = aquaculture; F = fishing village; C = commercial activity; R = research station; T = town.
[b] Abandoned.
[c] Seasonal fishing camp.
[d] Occasional guano mining (Bedolla-Guzmán *et al.* 2019).
[e] Includes salt mines, ports, and an airport.

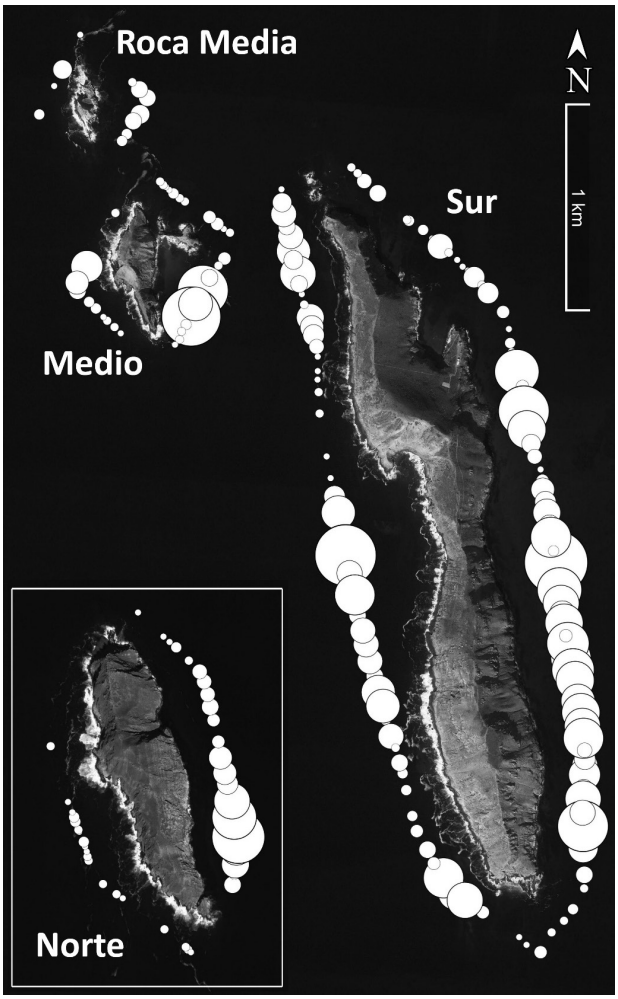

Fig. 2. Distribution of Scripps's Murrelet (white circles) during spotlight surveys around the four islets of Islas Coronado on 06–07 April 2005. Circles are scaled to the number of murrelets, from smallest to largest: 1 to 28 at Sur, 1 to 26 at Medio and Roca Media, and 1 to 23 at Norte.

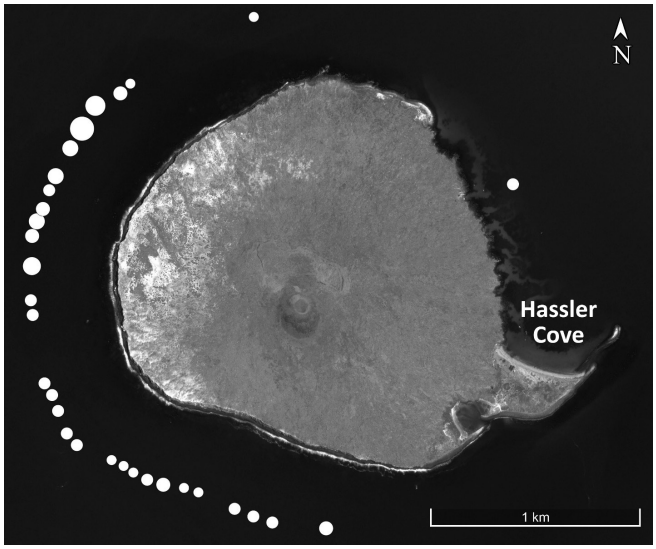

Fig. 4. Distribution of *Synthliboramphus* murrelets (white circles) during the spotlight survey around Isla San Martin on 22–23 April 2008. Circles are scaled to the number of murrelets from smallest (1) to largest (8).

METHODS

Research during 2002–2008 was conducted under permits (SGPA/DGVS/01915, SGPA/DGVS/12411, SGPA/DGVS/00318, SGPA/DGVS/00318/07, SGPA/DGVS/02719/07, SGPA/DGVS/03217/08, SGPA/DGVS/22940, SGPA/DGVS/4538, and 2513/2001) issued to E. Palacios and Grupo de Ecologia y Conservación de Islas by the Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT) and Secretaría de Gobernación. Capture and handling procedures

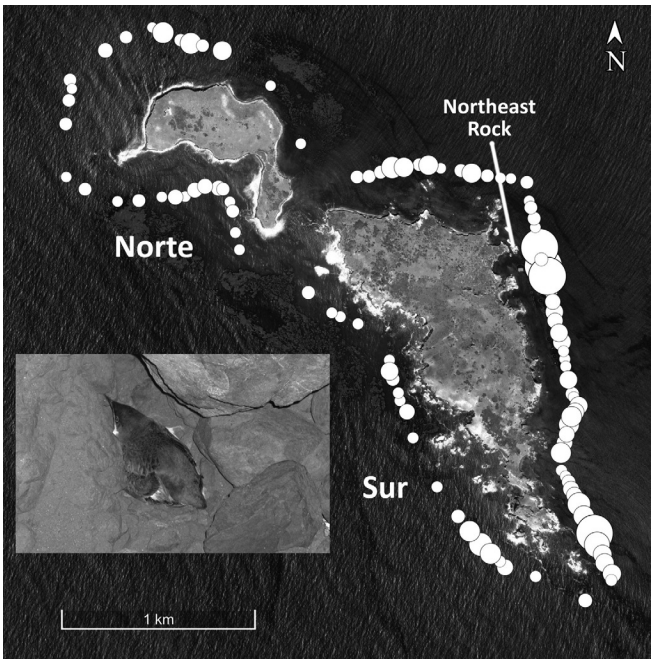

Fig. 3. Distribution of Scripps's Murrelet (white circles) during the spotlight survey around Islas Todos Santos on 06–07 May 2005. Circles are scaled to the number of murrelets, from smallest (1) to largest (13). Inset photo: incubating murrelet in crevice nest on Northeast Rock off Todos Santos Sur, 07 May 2005.

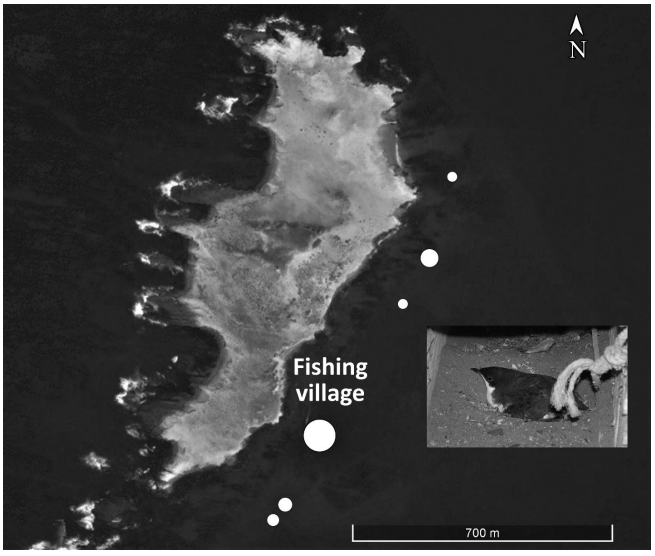

Fig. 5. Distribution of Scripps's Murrelet (white circles) during the spotlight survey on the east shore of Isla San Jeronimo on 21–22 April 2008. Circles are scaled to the number of murrelets from smallest (1) to largest (12). Inset photo: incubating murrelet inside a structure at the fishing village on San Jeronimo, 21 April 2008.

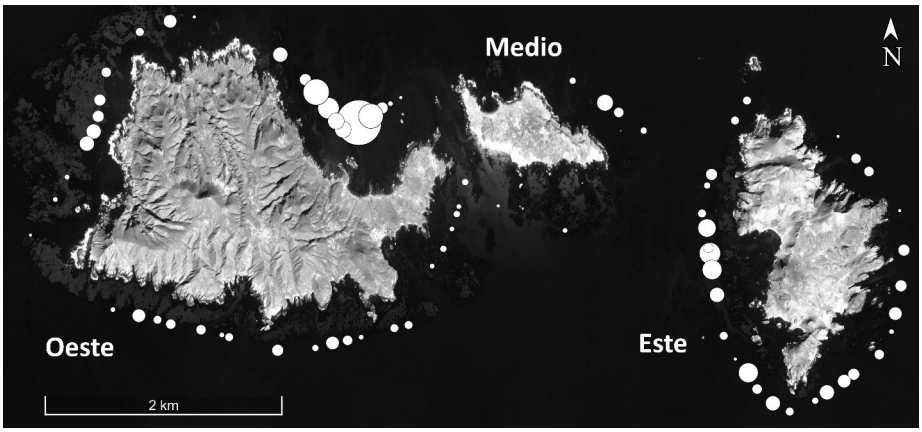

Fig. 6. Distribution of *Synthliboramphus* murrelets (white circles) during spotlight surveys around the islets of Islas San Benito on 28–29 March 2002. Circles are scaled to the number of murrelets from smallest (1) to largest (27).

followed the ethical standards and policies applicable in Mexico as presented in the *Guidelines to the Use of Wild Birds in Research* (Fair *et al.* 2010).

Spotlight surveys

We used spotlight surveys to determine the number and distribution of *Synthliboramphus* murrelets in nearshore congregations. Surveys were conducted from a 4-m inflatable vessel with an observer height approximately 1.5 m above the waterline. Other details of the spotlight survey technique are described in Whitworth & Carter (2014) and Whitworth *et al*. (2018a). Survey transects circumnavigated each island (except SJ; see below) at roughly 200 m from shore, but deviations (± 50–100 m) from the GPS transect sometimes occurred depending on topography and navigation hazards such as offshore rocks and kelp beds. We used single transects at CD, SM, and TS, but SB surveys consisted of separate transects around Oeste-Medio and Este, and IC surveys consisted of separate transects around each of the four islets. The SJ transect was limited to the east shore because dangerous surf over an extensive reef prevented safe transit off the west shore. Surveys were completed within one night at IC (17.5 km), TS (10.2 km), SM (9.1 km), SJ (1.9 km), and SB (21.8 km), but two nights (with two vessels on one night) were needed to complete the longer transect around CD (~110 km). The years and dates for spotlight surveys are presented in Table 2.

We estimated the size of SCMU breeding populations using a spotlight survey correction factor determined at Santa Barbara Island, California, which quantified the relationship between the mean number of murrelets counted in at-sea congregations and the number of nests on the adjacent shoreline (1.60 nests murrelet^{-1}; 95% confidence interval [CI] = 1.10–2.89; Whitworth *et al*. 2018a, 2018b). We applied this correction factor and the boundaries of the 95% CI to the single count at CD and mean counts at the other islands to estimate a range for population size. Counts were pooled across years if surveys were conducted in more than one year (Table 2). Mean counts at SM, SB, and CD were multiplied by the proportions of SCMU in the capture samples (Table 3) to obtain adjusted counts, which were then used to estimate population size.

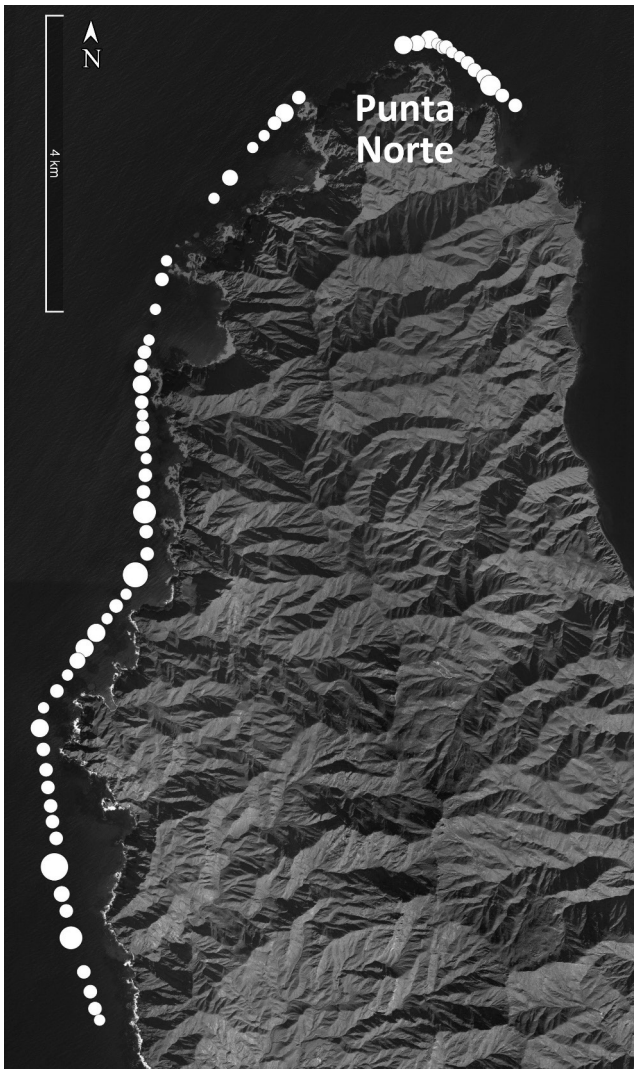

Fig. 7. Distribution of *Synthliboramphus* murrelets (white circles) off the north and northwest shore of Isla Cedros during the spotlight survey on 04–05 April 2007. Circles are scaled to the number of murrelets from smallest (1) to largest (8).

At-sea captures

We used the "night-lighting" technique to capture *Synthliboramphus* murrelets attending at-sea congregations in waters adjacent to all six islands (Whitworth *et al.* 1997; Table 3). The three-person capture-crew searched nearshore waters in an inflatable vessel using a high intensity spotlight to locate and disorient murrelets, and a long-handled dipnet (1.0–1.5 m) to capture targeted birds. We transported murrelets to a larger anchored vessel where: (1) species was determined based on facial patterns and coloration of underwing coverts (Jehl & Bond 1975); (2) breeding status was determined based on the presence of bilateral brood patches (Sealy 1976); and (3) blood samples were collected to examine phylogenetic relationships among the murrelet taxa in the region (Birt *et al.* 2012). Murrelets were held for ~10 min for processing before being released. Captures occurred after completion of spotlight surveys to avoid affecting counts.

Nest searches

We used hand-held flashlights to search for murrelet nests (i.e., incubating or brooding adults; chicks; and hatched, abandoned, or depredated eggs) in rock crevices and under dense bushes at all islands except SB (Table 4). We did not conduct nest searches at SB in 2002, but nest searches and/or monitoring were conducted there in 1999 (Keitt 2005) and 2003–2004 (Wolf *et al.* 2005). Search crews accessed potential breeding areas by inflatable boat. SM and SJ required a single drop-off after which crews were able to

TABLE 2
Summary of *Synthliboramphus* murrelets counted during spotlight surveys at Islas Coronado (IC), Todos Santos (TS), San Martin (SM), San Jeronimo (SJ), San Benito (SB), and Cedros (CD), off western Baja California (BC), Mexico in 2002–2008.

Island	Year(s)	Range of dates	Mean ± SD (*n*)	Adj. SCMU[a]	Pop. Est. (95% CI)
IC	2002, 2005	06 Apr–18 May	1015 ± 340 (5)	–	1624 (1117–2933)
TS	2005, 2007	06–28 May	238 ± 70 (3)	–	381 (262–688)
SM	2008	18–22 Apr	69 ± 15 (2)	17	27 (19–49)
SJ	2007, 2008	11–21 Apr	22 ± 4 (2)	–	35 (24–64)
SB	2002	27–28 Mar	344 ± 71 (3)	210	336 (231–607)
CD	2007	04–07 Apr[b]	168 (1)	30	48 (33–87)
Total BC					2451 (1686–4428)

[a] Mean counts were adjusted by the proportions of each murrelet species in the at-sea capture samples (Table 3) to estimate the number of Scripps's Murrelets (SCMU).
[b] Three survey nights were needed to complete the single round-island survey (110 km) at Cedros.

TABLE 3
Number of Scripps's (SCMU), Craveri's (CRMU), and Guadalupe (GUMU) murrelets captured at Islas Coronado (IC), Todos Santos (TS), San Martin (SM), San Jeronimo (SJ), San Benito (SB), and Cedros (CD) off western Baja California, Mexico during 2002–2008[a]

Island	Year	Date range (no. of nights)	SCMU	CRMU	GUMU
IC	2005	05 Apr–20 Jun (9)	95 (23)	–	–
TS	2005	06-07 May (1)	30 (2)	–	–
SM	2008	22–23 Apr (1)	2 (1)	5 (3)	1
SJ	2007	11–12 Apr (1)	16 (2)	–	–
	2008	20–22 Apr (2)	56 (11)	–	–
SB	2002	27–30 Mar (3)	27 (7)	–	17[b] (2)
CD	2007	08–09 Apr (1)	2	9 (4)	–

[a] Number of murrelets with brood patches are in parentheses.
[b] Includes three murrelets with intermediate facial patterns (*sensu* Jehl & Bond 1975).

TABLE 4
Number of Scripps's Murrelet nests found during searches at Islas Coronado (IC), Todos Santos (TS), San Martin (SM), San Jeronimo (SJ), and Cedros (CD) off western Baja California, Mexico during 2002–2008

Island	Year	Date range	Total	Nest Contents[a]			
				IA	HE	AE	BE
IC	2005	23 Mar–21 Jun	133[b]	–	68[b]	20[b]	30[b]
TS	2005	06-07 May	7	5	1	1	–
	2007	26 Mar–28 May	11	5	5	–	1
SM	2007	12 Apr	1[c]	–	–	–	1
	2008	19 Apr	–	–	–	–	–
SJ	2007	11 Apr	19	8	2	5	4
	2008	20–21 Apr	25	4	5	5	11
CD	2007	08–09 Apr	2[c]	–	2	–	–

[a] IA = incubating adult; HE = hatched egg(s); AE = abandoned or unattended egg(s); BE = broken or depredated egg(s).
[b] Nest contents for IC reflect the fate of monitored nests (number hatched, abandoned or depredated); the total includes 15 nests with unknown fates.
[c] Craveri's Murrelet eggs.

access potential breeding habitats on foot. However, IC, TS, and CD required multiple drop-offs at shoreline areas and offshore rocks that were deemed potential breeding habitats.

Potential breeding areas were generally searched only once each year, but we visited TS in March and May 2007 and conducted extensive nest searches and monitoring during seven trips to IC between 23 March and 21 June 2005 (California Institute of Environmental Studies [CIES], unpubl. data). Nest monitoring at IC covered three discontinuous shoreline plots (up to 10–15 m above the intertidal rocks) on the east side of IC Sur and the entirety of IC Roca Media. Adult murrelets visible in nests at IC, TS, and SJ were identified as SCMU based on facial coloration patterns (Jehl & Bond 1975). Nests where eggs provided the only evidence of breeding, or adults could not be identified, were assumed to be SCMU based on observations from visible nests and results of spotlight surveys at IC, TS, and SJ. Genetic analysis of eggshell DNA was used to identify eggs found in nests at SM and CD (Birt *et al*. 2008, 2012), where two or three murrelet species were captured from at-sea congregations.

RESULTS

Islas Coronado (IC)

The combined spotlight counts for the four IC islets in 2002 and 2005 ranged from 519 to 1315 murrelets (mean [$\bar{x}$] = 1 015 ± 340 standard deviation [SD]; n = 5; Table 2). Applying the spotlight survey correction factor to the mean count yielded a breeding population estimate of 1624 pairs (range = 1117–2933). Counts at the individual islets ranged from 409 to 933 murrelets ($\bar{x}$ = 681 ± 214) at Sur, 24 to 363 ($\bar{x}$ = 189 ± 122) at Norte, 72 to 156 ($\bar{x}$ = 105 ± 47) at Medio, and 17 to 53 ($\bar{x}$ = 41 ± 15) at Roca Media (Table 5). Breeding population estimates for the four islets were 1090 pairs (range = 749–1968) at Sur, 302 pairs (range = 208–546) at Norte, 168 pairs (range = 116–303) at Medio, and 66 pairs (range = 45–118) at Roca Media.

Murrelets were distributed continuously around Sur, but numbers were consistently highest off the east shore at the other three islets (Fig. 2). We captured 95 SCMU off the east shore of Sur during nine nights in 2005 (Table 3). Brood patches were present on 23 murrelets (24%). We found 133 active nests during extensive searches and monitoring in 2005 (Table 4), including 63 nests on Roca Media and 70 nests on Sur. All murrelets visible in nests were SCMU.

Todos Santos (TS)

Spotlight counts in 2005 and 2007 ranged from 174 to 313 murrelets ($\bar{x}$ = 238 ± 70; n = 3), which yielded a breeding population estimate of 381 pairs (range = 262–688; Table 2). Counts at the individual islets ranged from 119 to 250 murrelets ($\bar{x}$ = 182 ± 66) at Sur and 50 to 63 ($\bar{x}$ = 56 ± 7) at Norte, which yielded population estimates of 291 pairs (range = 200–526) and 90 pairs (range = 62–162), respectively (Table 5). Murrelets were distributed continuously around both islets, but numbers were consistently higher along the east shore of Sur (Fig. 3). We captured 30 SCMU off the east shore of Sur during a single night in 2005 (Table 3). Brood patches were present on two murrelets (7%).

We found seven nests during searches on the east shore of Sur in May 2005 and 11 nests during more extensive shoreline searches on Sur and Norte in May 2007 (Table 4). All murrelets visible in nests were SCMU. In 2005, five nests were in fissures on a large rock off northeast Sur (Northeast Rock), while the other two nests were found in a sea cave and large boulder pile, where we also discovered a storm petrel (*Oceanodroma* spp.) egg in a rockslide. Only one of the murrelet nests on Northeast Rock was occupied in 2007. Ten other nests were found on the west (four nests), east (three nests), and north (three nests) shores of Sur. We also found one Cassin's Auklet nest on the north shore of Sur in 2007.

San Martin (SM)

We counted 58 and 79 murrelets ($\bar{x}$ = 69 ± 15) distributed mainly off the west shore during two surveys in 2008 (Table 2; Fig. 4). Two of the eight murrelets (25%) captured at SM were SCMU, one of which had a brood patch (Table 3). Based on the proportion of SCMU (25%) in the capture sample, the adjusted spotlight count

TABLE 5
Summary of *Synthliboramphus* murrelets counted during spotlight surveys conducted at the islets of Islas Coronado (IC), Todos Santos (TS), and San Benito (SB) off western Baja California, Mexico during 2002–2007

Island	Islet	Year(s)	Mean ± SD (n)	Adjusted SCMU[a]	Population Estimate (95% CI)
IC	Sur	2002, 2005	681 ± 214 (5)	–	1090 (749–1968)
	Norte	2002, 2005	189 ± 122 (5)	–	302 (208–546)
	Medio	2002 2005	105 ± 47 (5)	–	168 (116–303)
	Roca Media	2002, 2005	41 ± 15 (5)	–	66 (45–118)
TS	Sur	2005, 2007	182 ± 66 (3)	–	291 (200–526)
	Norte	2005, 2007	56 ± 7 (3)	–	90 (62–162)
SB	Oeste	2002	166 ± 59 (3)	101	162 (111–292)
	Medio	2002	21 ± 3 (3)	13	21 (14–38)
	Este	2002	157 ± 23 (3)	96	154 (106–277)

[a] Mean counts were adjusted by the proportion (61%) of Scripps's Murrelets (SCMU) in the at-sea capture sample at SB (Table 3) to obtain an estimate for the number of SCMU.

was 17 murrelets, which yielded a population estimate of 27 pairs (range = 19–49; Table 2). Evidence of murrelet breeding was limited to eggshell fragments (later confirmed as CRMU; Birt *et al*. 2008) in what was considered a "suitable nest site" located among shacks in the fishing village at Hassler Cove (Fig. 4). Other results from SM are available in Whitworth *et al.* (2018a).

San Jeronimo (SJ)

Spotlight counts in 2007 and 2008 totaled 19 and 24 murrelets ($\bar{x}$ = 22 ± 4), respectively, and yielded a breeding population estimate of 35 pairs (range = 24–64; Table 2). Murrelets were sparsely distributed along the east shore, mainly off the southeast coast (Fig. 5). We captured 72 murrelets, including 16 over one night in 2007 and 56 over two nights in 2008 (Table 3). All captured murrelets were SCMU. Two murrelets (13%) captured in 2007 and 11 (20%) captured in 2008 had brood patches.

We found 19 SCMU nests during searches in and around the fishing village in 2007. In 2008, we found 25 nests during more extensive searches of the shoreline and in some interior areas where we could walk without collapsing the abundant Cassin's Auklet burrows (Table 3). All murrelets visible in nests were SCMU. Village structures harbored most nests in 2007 (89%) and 2008 (60%). We noted considerable evidence of egg predation by mice, particularly in 2008. There was little evidence of avian predation on SCMU (two carcasses in 2007) despite the presence of a Barn Owl *Tyto alba* nest with four eggs in 2007 and a Peregrine Falcon *Falco peregrinus* nest with three small chicks in 2008. However, we discovered 11 auklet carcasses scattered widely around SJ in 2008.

San Benito (SB)

Combined spotlight counts ranged from 281 to 421 murrelets (x = 344 ± 71; n = 3) in 2002 (Table 2). We observed three family groups (i.e., adults escorting chicks departing the island) during our surveys in late March. Based on 61% SCMU in the capture sample, the adjusted spotlight count was 210 murrelets, which yielded a population estimate of 336 pairs (range = 231–607; Table 2). Counts at the islets ranged from 128 to 234 murrelets ($\bar{x}$ = 166 ± 59) at Oeste, 131 to 176 murrelets ($\bar{x}$ = 157 ± 23) at Este, and 17 to 23 murrelets ($\bar{x}$ = 21 ± 3) at Medio (Table 5). The mean adjusted spotlight counts were 101 murrelets at Oeste, 96 murrelets at Este, and 13 murrelets at Medio, which yielded population estimates of 162 pairs (range = 111–292) at Oeste, 154 pairs (range = 106–277) at Este, and 21 pairs (range = 14–38) at Medio (Table 5).

Murrelets were most numerous in a cove on the north side Oeste but were sparser around the remainder of Oeste and Medio (Fig. 6). In contrast, murrelets were evenly distributed around Este, except at the extreme north end. We captured 44 murrelets over three nights in 2002, including 27 SCMU, 14 GUMU, and three murrelets with intermediate face patterns (Jehl & Bond 1975; Table 3). Seven (26%) of the SCMU had brood patches, but just three (18%) of the GUMU/intermediate murrelets had brood patches.

Cedros (CD)

We counted 168 murrelets during the single round-island survey in 2007 (Table 2). Most murrelets (90%) were located along the rugged north and northwest shoreline (Fig. 7). Two of the 11 murrelets captured (18%) were SCMU, but neither had brood patches (Table 3). Based on 18% SCMU in the capture sample, the adjusted spotlight count was 30 SCMU, which yielded a population estimate of 48 pairs (range = 33–87; Table 2). Evidence of murrelet breeding consisted of three hatched eggshells in two crevices found during nest searches in six shoreline areas and two offshore rocks (Table 4). Analysis of DNA confirmed the eggs were CRMU (Birt *et al*. 2008). Other results from CD are available in Whitworth *et al.* (2018a).

DISCUSSION

Historical and current status of Scripps's Murrelet in Baja California

Although our spotlight surveys in the western BC islands were conducted 11–17 years ago, these data provide the most recent and complete population estimates for SCMU in the region, as well as a reliable modern baseline for measuring future population trends soon after the eradication of introduced mammals at most of these islands in the late 1990s. SCMU were long known or suspected to breed at five of the six BC islands where we detected them in 2002–2008 (Jehl & Bond 1975, Drost & Lewis 1995, Keitt 2005), but a historical baseline before human impacts is not available and the lack of standardized studies prior to 1999 has permitted only speculative assessments of historical population trends. Long-term declines probably occurred at most islands after the introduction of cats (McChesney & Tershy 1998), although other factors likely affected murrelets at some islands (see below). Jehl & Bond (1975, pg. 11) suggested that SCMU on TS, SM, and SJ had "apparently been extermined by rats or feral cats…", citing the observations of Howell (1912) and Van Denburgh (1924) at TS as evidence. The presumption of possible SCMU extirpation has continued to this day (e.g., Drost & Lewis 1995, McChesney & Tershy 1998, Bedolla-Guzmán *et al*. 2019) despite the lack of focused and detailed surveys to detect murrelets prior to 1999. While cats undoubtedly devastated murrelet (and other seabird) colonies off BC through most of the 20th century, evidence indicates that remnant murrelet populations persisted in isolated habitats (e.g., offshore rocks and sea caves) on most islands but went undetected during the infrequent (at best) expeditions. The most convincing evidence supporting this conclusion was the significant murrelet populations detected on TS, SM, and SJ in 1999 just after cat eradication in 1998–1999 (Keitt 2005). Murrelets also persevered despite the presence of cats at IC Sur and Norte through the 1990s (see *Islas Coronado* section below), and currently persist in isolated habitats at CD, where cats and other predators are still present. Given the lack of reliable data before 1999, confirming extirpation at TS, SM, and SJ may never be resolved; if extirpation did occur, recolonization occurred rapidly and naturally.

Evidence from monitoring programs have demonstrated that seabird populations often increased rapidly following the removal of introduced predators (e.g., SCMU increased by more than 12% per annum in the 12 years after rat eradication at Anacapa Island; Whitworth & Carter 2018a). We suspect that the removal of cats probably allowed murrelet population increases at the smaller BC islands since 1999, but quantitative data proving that increases occurred is lacking. Standardized murrelet call counts and nest searches determined the presence and relative levels of colony size at most western BC islands in 1999, but interpreting vocal activity proved difficult, and the resulting population estimates were subjective (Keitt 2005). Still, we could sometimes infer

major population trends by comparing data from the 1999 and 2002–2008 surveys (see island summaries below). More recent studies in 2013–2017 reported only the number of nests found on BC islands (Bedolla-Guzmán *et al.* 2019). Given the large amount of inaccessible breeding habitat at most of these islands, nest counts clearly underestimated population size relative to spotlight counts. Thus, while nest counts were useful for determining murrelet presence/absence and can be used to assess population trends (if adequate samples of nests are located and monitored over time), they were not adequate for estimating population size. A monitoring plan is being developed for *Synthliboramphus* murrelets that will address the limitations of past studies and permit reliable assessments of population size and trends in the future. Ideally, this monitoring plan would include: 1) annual nest monitoring to assess population trends at IC, SB, and TS, where adequate samples of nests are available; and 2) a rotating schedule of spotlight surveys and at-sea captures at all breeding islands to determine population size and species presence, and to confirm trends based on nest monitoring.

Below, we have summarized the scant historical and recent information available for SCMU at their six breeding islands off BC.

Islas Coronado (IC)

The first murrelets associated with IC were two SCMU (University of Kansas Biodiversity Institute Ornithology Collection #71792–71793; Appendix 1, available on the website) collected in May 1884. SCMU were later confirmed breeding in 1893 (US National Museum [USNM] #B23619, Appendix 1; Carter *et al.* 2005), which was the first nest documented for this species after their initial description in 1859 (Baird 1859). IC was visited frequently by ornithologists and egg collectors throughout the late 19th and early 20th centuries, but published literature during this period rarely included even qualitative estimates of population size, and the scant information that was provided was vague and often contradictory (Grinnell & Daggett 1903; Lamb 1909; Osburn 1909, 1911; Wright 1909; Howell 1910, 1917; Stephens 1921). In June 1908, Wright (1909) mentioned several old nests and observed a family group at sea near IC, while Lamb (1909) reported finding over 25 murrelet nests but gave no estimate of total numbers present. Howell (1910, pg. 184) described murrelets as "breeding in limited numbers" in 1910, but later as "abundant on all four islands…" in 1917 (Howell 1917, pg. 22), further noting that "… cats on south island… make sad inroads on the birds that venture to nest there." Cats had been introduced on Sur sometime before 1908 (Wright 1909, McChesney & Tershy 1998). By May 1919, H. Edwards described SCMU as still "fairly plentiful, two of us taking about twenty sets in two hours…" (Western Foundation of Vertebrate Zoology [WFVZ] #45500; Appendix 1). We suspect that the SCMU population had declined substantially by 1940 due to the combined effects of cat predation, egg and bird collecting (a minimum of 753 specimens were collected at IC from 1900 to 1940; Appendix 1), and high levels of avian predation. Howell (1910, pg. 186) noted Peregrine Falcons as causing "fearful damage among the murrelets and auklets." Much less information was available from 1941 to 1988, although murrelets were still present based on museum specimens collected in 1948, 1951, 1961, 1968–1970, and 1980 (Appendix 1).

The first quantitative population estimates for IC were provided in 1988–1990 when R. Pitman and W. Everett (unpubl. data) estimated 100 nests on Sur, 200 on Norte, 50 on Medio, and 35 on Roca Media. These estimates were based on nest searches at Roca Media and unspecified assumptions at the other three islets. In 1995, counts of SCMU calls in at-sea congregations recorded vocal activity at Sur (maximum 274 calls in 15 min, the interval used hereafter) and Norte (maximum 186 calls) that was comparable to Santa Barbara Island in the mid-1990s (DLW unpubl. data). Clearly, a relatively large murrelet population persisted prior to the eradication of cats on Norte in 1995 and Sur in the late 1990s. In 1999, Keitt (2005) estimated 750–1500 pairs, based mainly on very high vocal activity at Sur (maximum 253 calls) and Norte (maximum 168 calls), as only eight nests were found during searches in mid-April. Our impression in 2002–2005 was that the SCMU population was likely closer to the upper end of the estimated range (2933 pairs; Table 2), which is over seven times greater than in 1988–1990 and nearly double that in 1999. The lack of comparable standardized data makes it difficult to quantify the extent of population decreases before, or increases after, the eradication of cats, but IC has clearly harbored the largest SCMU colony off BC for many decades and may now host the largest colony in the world.

The only quantitative data reported from nest "censuses" in 2013–2017 was 22 nests on Sur and 15 nests on Norte (Bedolla-Guzmán *et al.* 2019). We did not search on Norte, but our count for Sur (70 nests) was more than three times higher than in 2013–2017. We suspect there was little overlap in the areas searched on Sur between these studies, so population decreases based on comparisons of nest counts should not be assumed. Future studies at IC should include spotlight surveys and nest monitoring, which will allow comparison with the extensive murrelet monitoring conducted there in 2005–2007 (CIES, unpubl. data).

Todos Santos (TS)

In contrast to the rich history of SCMU egg collections at IC, there is very little information for TS. The first mention of murrelets in the historic literature was that they were "fairly common on or about Todos Santos…" in March 1897 (Kaeding 1905). However, Howell (1912, pg. 188) reported no SCMU despite "diligent" searches in 1910 and was convinced that "no small seabirds bred upon the islands because of the plague of rats," likely referring to endemic Anthony's Wood Rats *Neotoma anthonyi*, which were later extirpated by cats. Fears of seabird extirpation at the time were probably unfounded, as Willet (1913) reported small numbers of Cassin's Auklets breeding in April 1912. None of these accounts mentioned cats or depredated murrelet/auklet carcasses until May 1923, when Van Denburgh (1924, pg. 68) reported "several [SCMU] eaten by cats…found on various parts of the South Island." He also mentioned murrelets calling and flying by the camp at night, as well as a "broken eggshell" found far from any potential nest site. The first documented nest was found in May 1940, when two eggs were collected from under an adult SCMU (WFVZ #145114; Appendix 1). To our knowledge, no nests were found between 1940 and 1998.

Cats were removed from both islets by 1999 (Keitt 2005). In the same year, Keitt (2005) found no nests but did hear significant numbers of murrelet calls (maximum 56 calls) off Sur and estimated < 50 breeding pairs. Considering the small number of nests found in 2005–2007, we suspect the population tended toward the lower end of the range estimated from spotlight surveys (i.e., 231 pairs; Table 2). Thus, assuming the earlier estimate was accurate, the population probably increased about 5-fold between 1999 and

2005–2007. In 2013–2017, Bedolla-Guzmán *et al.* (2019) reported 19 nests at Norte and 90 nests at Sur, suggestive of an ongoing population increase in the 15 years after cat eradication.

San Martin (SM)

Murrelets had never been documented breeding on SM despite accounts describing them as "fairly common on and about…San Martin..." in 1897 (Kaeding 1905, pg. 107), "present in some numbers" at sea between SM and San Quintín in April 1910 (Howell 1911, pg. 151), and "Heard each evening in the bay. Several sighted on the way to San Quentin" in July 1913 (Wright 1913, pg. 208). An adult SCMU was collected near SM in February 1950 (Museum of Vertebrate Zoology, UC Berkeley #120247; Appendix 1), adult CRMU were collected in 1951 and 1965 (Whitworth *et al*. 2018a), and a murrelet carcass was collected in 1977 (Natural History Museum of Los Angeles County #115403; Appendix 1); however, none of these observations confirmed breeding. The CRMU eggshells found in 2007 were the first proof of breeding at SM (Whitworth *et al*. 2018a)

In 1999, Keitt (2005) estimated < 50 pairs based on low vocal activity (maximum 10 calls), but no nests were found. These murrelets were all presumed to be SCMU, although we considered it likely SCMU, CRMU, and possibly GUMU were all present. Combining SCMU (27 pairs [range = 19–49]), CRMU (69 pairs [range = 47–124]; Whitworth *et al*. 2018a), and GUMU (14 pairs [range = 10–26]; CIES unpubl. data), our overall estimate was 110 pairs (range = 76–199), which was considerably greater than the upper boundary of the 1999 estimate. A 50% to 200% increase in the overall murrelet population eight years after cat eradication would not be surprising. Bedolla-Guzmán *et al*. (2019) reported SCMU and CRMU both as "probable breeders" in 2013–2017 but did not provide justification for this assessment.

The only evidence for SCMU breeding at SM was the two birds captured (one with brood patches) separately in April 2008. While CRMU outnumbered SCMU and GUMU in our capture sample, the proportions of each species were based on a small sample (eight birds) that may not have been representative of actual species ratios. Thus, SCMU (and GUMU) should be considered possible breeders and the population estimates should be considered tentative until more spotlight surveys and at-sea captures are completed. The consistent presence of SCMU, CRMU, and GUMU over several years would provide more convincing evidence of breeding and better estimates of population size (e.g., GUMU at San Clemente Island; Whitworth *et al.* 2018b).

San Jeronimo (SJ)

Although Kaeding (1905) described murrelets as "fairly common on and about" SJ, the first and only record of nesting prior to 1999 was eggs collected in 1932 (US National Museum [USNM] #B46624; Appendix 1). The lack of SCMU records is notable, considering the large number of Cassin's Auklets collected at the enormous colony in the late 19th and early 20th centuries (Kaeding 1905, Willett 1913). We located 173 auklet specimens collected between 1887 and 1968, and we considered it highly unlikely that collectors would have ignored or overlooked murrelets had they been breeding in substantial numbers. Instead, we believe the murrelet population was probably limited by competition for nesting crevices with auklets.

In 1999, Keitt (2005) estimated < 100 pairs based on moderate vocal activity (maximum 86 calls), five nests, and six adult murrelets seen on the ground at night. All murrelets observed in nests and on the ground at SJ in 1999 were SCMU (Keitt 2005). Depending on the interpretation of "< 100 pairs," our 2007–2008 population estimate (range = 24–64 pairs) could be considered somewhat lower, or in general agreement, with that in 1999, but not indicative of a population increase. In contrast, the greater number of nests (4–5 times) we found in 2007–2008 compared to 1999 was suggestive of a population increase, although differences in search effort could also have been responsible. Bedolla-Guzmán *et al.* (2019) reported only nine nests in 2013–2017, but this alone was not convincing proof of population decline after 2008. Data from 1999 to 2017 suggests SJ is the only BC island where SCMU have not benefitted measurably from cat eradication, possibly because population growth is being suppressed by competition for nesting crevices with the expanding auklet population (Bedolla-Guzmán *et al*. 2019).

San Benito (SB)

SB is the only BC island where SCMU, GUMU, and recently, CRMU, were confirmed to breed sympatrically (Jehl & Bond 1975, Wolf *et al.* 2005, Bedolla-Guzmán *et al.* 2019). Prior to 2012, SCMU and GUMU were considered one species, the former Xantus's Murrelet *S. hypoleucus* (Chesser *et al*. 2012), and the new taxonomy has not been updated in some museum databases. Based on museum specimens, the first breeding record at SB was a presumed SCMU egg (WFVZ #11804; Appendix 1) found abandoned in 1896. Kaeding (1905, pg. 107) described murrelets as breeding "accessibly on San Benitos" compared to TS, SM, and SJ; this was borne out by the relatively large number of museum specimens (25 egg sets and 59 birds) collected at SB from 1896 to 1976 (Appendix 1).

Drost & Lewis (1995) estimated "about 1,000?" breeding individuals (~500 pairs) in the mid-1990s, but also cautioned that "no systematic survey data" were available to support this estimate. Keitt (2005) estimated 300–750 pairs based on moderate vocal activity (maximum 82 calls) and 28 nests found on Oeste (9), Medio (3), and Este (16) in 1999. Combining SCMU (336 pairs [range = 231–607]) and GUMU (214 pairs [range = 147–387]; CIES unpubl. data), we estimated 550 pairs (range = 378–994), which was very similar to the 1999 estimate and suggested little change between 1999 and 2002. Wolf *et al*. (2005) reported 29 nests on Oeste in 2003 and 25 nests in 2004, with greater search effort likely responsible for the higher numbers on Oeste compared to 1999. Bedolla-Guzmán *et al*. (2019) reported 174 murrelet nests in 2013–2017. Part of the increase in nests between 2003–2004 and 2013–2017 may, again, have resulted from expanded search efforts, but the extent of the increase (six to seven times greater) strongly suggests population growth, as might be expected following the cat eradication in 1998. Future spotlight surveys and at-sea captures at SB would be helpful to confirm the population trends suggested by nest searches.

Cedros (CD)

There were no records or presumptions of breeding for any murrelet species at CD until two CRMU nests were confirmed in 2007 (Whitworth *et al.* 2018a), although Keitt (2005) noted an abundance of potential nesting habitat that had never been examined. The only

evidence for SCMU breeding was the two birds (neither with brood patches) we captured separately on one night in April 2007. To our knowledge, surveys had not been conducted at CD before, and have not been conducted since, we discovered the first nests in 2007. Additional spotlight surveys and at-sea captures are urgently needed to detect CRMU and SCMU, which are restricted to isolated nesting refuges where the small remnant populations are protected from terrestrial predators. While CRMU are confirmed to breed on CD, SCMU should be considered a possible breeder and the population estimate tentative until more spotlight surveys and at-sea captures are completed.

Estimating population size with spotlight surveys

The importance of spotlight surveys as a population monitoring and estimation tool for *Synthliboramphus* murrelets has been previously demonstrated and discussed (Whitworth & Carter 2014, 2018a, 2018b; Whitworth *et al.* 2018a, 2018b). One potential issue with our population estimates was the validity of the spotlight survey correction factor at BC islands. At-sea congregations serve primarily as social gatherings attended by breeding and non-breeding birds throughout the nesting season; they also serve as staging areas for murrelets visiting adjacent nesting areas (Whitworth *et al.* 1997, Hamilton *et al*. 2011). We doubt that significant geographic differences occur in congregation attendance patterns among the three *Synthliboramphus* species off BC and California because spotlight counts have exhibited similar nightly and seasonal variability at all the islands surveyed to date (e.g., Whitworth & Carter 2014; Whitworth *et al.* 2014, 2018b; CIES unpubl. data). While the factors affecting this variability were not completely understood, the correction factor incorporates a wide 95% CI that accounts for the variability at Santa Barbara Island, which we assumed was similar to the variability at the BC islands. Additional studies off BC, employing concurrent spotlight surveys and nest searches over several years, are desirable to better quantify variability in spotlight counts and to refine the correction factor, which we still consider a preliminary value. Fortunately, population estimates based on spotlight counts can be modified if future studies refine the correction factor, although prospects for such surveys in the near future are bleak.

Ideally, our efforts off BC would have included more spotlight surveys and at-sea captures to ensure that the samples accurately reflected population size and the proportions of each species at each island. However, we prioritized preliminary surveys at more islands over detailed surveys at a few key colonies. In retrospect, this was probably a correct decision as our wider survey coverage allowed us to discover CRMU colonies at CD, SM, Asunción, and San Roque (Whitworth *et al.* 2018a). Unfortunately, we were not able to conduct more extensive surveys off BC after 2008. Despite the small survey samples (≤ 3; Table 2) at all islands except IC, we felt the estimated ranges of population size corresponded with our general impression of colony size. While these ranges were rather wide, we believe they best reflected the status of BC murrelet colonies in 2002–2008 given the small survey samples. We were very encouraged by the parallels between our estimates and the number of nests found at IC Roca Media (63 nests vs. 66 pairs; range = 45–118) and SJ (25 nests vs. 35 pairs; range = 24–64), the only two islands where we were able to conduct searches over all suitable breeding habitats. In contrast, the large discrepancies between estimates and the number of nests found at TS, SM, and CD could be adequately explained by the extensive breeding habitats that were not accessible.

Regional and worldwide breeding population

The combined population estimate for all six SCMU breeding islands in the BC region was 2451 pairs (1686–4428; Table 2). Islas Coronado accounted for 66% (Coronado Sur alone accounted for 44%), while Todos Santos accounted for 16%, San Benito 14%, Cedros 2%, and San Jeronimo and San Martin 1% each. Using the correction factor with spotlight surveys conducted at the six breeding islands off southern California in 2004–2014 yielded 3591 pairs (range = 2469–6487; Whitworth *et al.* 2014; Whitworth *et al.* 2018b; Whitworth & Carter 2018a, 2018b; CIES unpubl. data) for a range-wide world population of 6042 pairs (range = 4155–10 915). Thus, the six BC islands accounted for approximately 41% of the world breeding population of SCMU. Our world population estimate for SCMU is similar to the 6950–10 500 pairs of murrelets in North America estimated by Karnovsky *et al.* (2005). The latter study was based on generalized additive models of shipboard and aerial surveys conducted across the species pelagic range from 1975 to 2003, although the earlier estimate probably included GUMU from Isla Guadalupe, small numbers of CRMU from Islas Asunción and San Roque, and possibly some CRMU dispersing from colonies in the Gulf of California (Fig.1).

Historical breeding by SCMU has also been reported at Islas Natividad, Asunción, and San Roque off west-central BC (Fig. 1), although the evidence supporting species identity is inconclusive (Bancroft 1927, Lamb 1927, Drost & Lewis 1995, Whitworth *et al*. 2018a). We confirmed CRMU breeding at Asunción and San Roque, and captured CRMU at San Roque in 2007, but found no evidence of SCMU at either island. Furthermore, only CRMU nests were reported at these three islands in 2013–2017 (Bedolla-Guzmán *et al.* 2019). A previous report of sympatric breeding by CRMU and SCMU at San Roque and Asunción in 2014 was apparently erroneous (see Whitworth *et al.* 2018a). Therefore, we consider it likely that only CRMU bred historically, or currently breed, at these islands. To resolve any future confusion surrounding the status of murrelets, an ongoing program of spotlight surveys, at-sea captures, and nest monitoring are needed at Asunción, San Roque, and especially Natividad, where surveys of the at-sea congregation have not yet been conducted.

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