BREEDING OF CRAVERI'S MURRELET *SYNTHLIBORAMPHUS CRAVERI* AT FOUR ISLANDS OFF WEST-CENTRAL BAJA CALIFORNIA, MÉXICO

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ABSTRACT

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Breeding by Craveri's Murrelet (CRMU) has been documented on many islands in the Gulf of California, México, but has never been convincingly demonstrated on islands off the west coast of Baja California (BC). In 2007–2008, we confirmed CRMU breeding at Islas San Roque (n = 1 nest), Asunción (n = 2), Cedros (n = 2), and San Martín (n = 1) off west-central BC, using genetic analysis of eggshell membranes to confirm species identity. Spotlight surveys of *Synthliboramphus* murrelets attending at-sea congregations recorded 9–14 murrelets (n = 1 survey) at San Roque, 24–25 at Asunción (n = 1), 168 at Cedros (n = 1), and 69 (± 15 SD; n = 2) at San Martín. All murrelets captured in at-sea congregations at San Roque (n = 6) were CRMU, but two species (82% CRMU, 18% Scripps's Murrelet *S. scrippsi* [SCMU]) were captured at Cedros (n = 11), and three species (63 % CRMU, 25% SCMU, 13% Guadalupe Murrelet *S. hypoleucus*) were captured at San Martín (n = 8). Applying a spotlight survey correction factor that quantified the relationship between the number of murrelets attending at-sea congregations and the number of nests on the adjacent shoreline, we tentatively estimated 14–22 CRMU pairs (95% C.I. = 10–40 pairs) at San Roque, 38–40 (95% C.I. = 26–72) at Asunción, 221 (95% C.I. = 152–399) at Cedros and 69 (95% C.I. = 47−124) at San Martín. To our knowledge, these are the first population estimates for any CRMU colony. Confirmation of CRMU breeding at these four islands increased our understanding of *Synthliboramphus* murrelet distribution in the region, lending credence to presumed historical breeding by CRMU at Islas Natividad and San Benitos (where breeding has since been confirmed). More spotlight surveys, at-sea captures, and nest searches are needed to better determine the presence, size, and species composition of the murrelet populations on either side of BC.

Key words: Baja California, Craveri's Murrelet, Isla Asunción, Isla Cedros, Isla San Martín, Isla San Roque, *Synthliboramphus craveri*

INTRODUCTION

Craveri's Murrelet *Synthliboramphus craveri* (CRMU) is the most southerly breeding auk (Family Alcidae) and is also the least studied of all the North American auks.

Historically, direct evidence of breeding by CRMU has been restricted to 22 islands in the Gulf of California off the east coast of Baja California (BC), México, although breeding is currently considered likely on just 12 islands (Bancroft 1927, 1930; Grinnell 1928, Friedmann *et al*. 1950, DeWeese & Anderson 1976, Breese *et al*. 1993, Velarde *et al*. 2011). In contrast, the historical status of CRMU on the Pacific side of BC is rather muddled (Anthony 1900, Cooke 1916, Van Rossem 1926, Jehl & Bond 1975, Violani & Boano 1990, Bowen 2013; see Discussion). CRMU have been infrequently encountered during the breeding season at Islas San Benito and Natividad (e.g., Jehl & Bond 1975), but breeding has never been convincingly demonstrated at these or any other island off western BC.

As for all *Synthliboramphu*s murrelets, determining the size, and sometimes even the presence, of CRMU colonies is difficult because they nest in rock crevices, often in remote and inaccessible breeding habitats (e.g., cliffs, sea caves, and offshore rocks) where they are active only at night (DeWeese & Anderson 1976, Murray *et al*. 1983, Breese *et al*. 1993, Velarde *et al*. 2011, California Institute of Environmental Studies [CIES], unpubl. data). Nocturnal spotlight surveys (Whitworth & Carter 2014) and night-lighting captures (Whitworth et al. 1997) of *Synthliboramphus* murrelets attending nearshore at-sea congregations adjacent to breeding colonies have been used to locate, monitor and determine the size of colonies in California, México, Japan and South Korea (Whitworth *et al*. 2014, 2018; Whitworth & Carter 2018a, 2018b; D.L.W. unpubl. data), but these techniques have never been used for CRMU. In fact, we are not aware of population size or trend estimates for any CRMU colony.

During 2007–2008, we conducted the first spotlight surveys and at-sea captures of *Synthliboramphus* murrelets at six islands (San Martín, San Jerónimo, Cedros, Guadalupe, San Roque, and Asunción; Fig. 1) off the Pacific coast of west-central BC. Scripps's Murrelet *S. scrippsi* (SCMU) and Guadalupe Murrelet *S. hypoleucus* (GUMU), former subspecies of Xantus's Murrelet *S. hypoleucus* (Chesser *et al*. 2012), have been known or suspected to breed on at least five of these islands (all except Cedros; Jehl & Bond 1975, Drost & Lewis 1995, Carter *et al*. 2005, Keitt 2005). During our 2007–2008 surveys, we discovered CRMU nests and significant numbers of individuals in congregations at four islands where breeding had not previously been recorded: San Roque,

Asunción, Cedros, and San Martín. In this paper, we present the results of our spotlight surveys, at-sea captures, and nest searches to determine the status and distribution of CRMU at Islas San Roque, Asunción, Cedros, and San Martín; estimate the size of CRMU populations at each island; and discuss the history of CRMU at islands off west-central BC.

STUDY AREA

Islas Asunción (27°06´N, 114°17´W), San Roque (27°09´N, 114°22´W), Cedros (28°10´N, 115°13´W), and San Martín (30°29´N, 116°06´W) lie across a 400+ km expanse of the Pacific coast off the western BC peninsula (Fig. 1). Asunción (46 ha; max. elevation 40 m) and San Roque (39 ha; 15 m) are very small, sparsely vegetated, low-elevation islands, lying 10 km apart and < 2 km off the BC coast about 100 km SE of Punta Eugenia (Fig. 1). San Martín (~265 ha; 127 m) is a small, densely vegetated island lying just 5 km off the coast about 300 km NNW of Punta Eugenia. Cedros (~34 800 ha; 1 205 m) is the largest island on the Pacific side of the BC peninsula and is located 45 km NNW of Punta Eugenia. Asunción and San Roque are both uninhabited, but San Martín hosts a small seasonally occupied fishing village and Cedros has several developed areas (e.g., permanent settlements, tourist facilities, fishing villages and cooperatives, mines, docks, and an airport) located mostly on the less rugged south and southeast coasts. Non-native mammals have been introduced on all four islands and are currently abundant on Cedros, but introduced mammals were removed from Asunción and San Roque in 1994, and from San Martín in 2000 (McChesney & Tershy 1998, Keitt 2005). All four islands are now protected within Mexican biosphere reserves. San Roque and Asunción were incorporated into the El Vizcaíno Biosphere Reserve in 1988, and Cedros and San Martín were incorporated into the Pacific Islands of Baja California Biosphere Reserve in 2016.

Fig. 1. *Synthliboramphus murrelet* breeding islands on the west coast of Baja California, México. Craveri's Murrelet was documented breeding at Islas San Martín, Cedros, San Roque, and Asunción during 2007–2008, while historical breeding was suspected and recently confirmed at Islas San Benitos and Natividad.

METHODS

Our research during 2007–2008 was conducted under four permits (SGPA/DGVS/00318/07, SGPA/DGVS/02719/07, SGPA/DGVS/03217/08, and SGPA/DGVS/22940) issued to E. Palacios by the Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT). Capture and handling procedures followed the ethical standards and policies applicable in México as presented in the *Guidelines to the Use of Wild Birds in Research*.

At-sea captures

We used a "night-lighting" technique described by Whitworth *et al.* (1997) to capture *Synthliboramphus* murrelets attending at-sea congregations in waters adjacent to Islas San Martín, Cedros, and San Roque (Table 1). The three-person capture crew (i.e., boat driver, net handler, and spotlighter) searched nearshore waters in an inflatable vessel using a high intensity spotlight to locate murrelets, and a long-handled dipnet (1.0–1.5 m) to capture targeted birds. We transported captured murrelets to the research vessel *Alguita* where we: (1) identified species based on facial patterns and coloration of underwing coverts (Jehl & Bond 1975); (2) determined breeding status based on presence of bilateral brood patches (Sealy 1976); and (3) collected blood samples to examine phylogenetic relationships among the *Synthliboramphus* murrelet taxa in the region (Birt *et al*. 2008, 2012). Murrelets were held 10–15 min for processing before being released. Captures at San Roque on 8–9 April 2007, and at San Martín on 22–23 April 2008, occurred after completion of spotlight surveys to avoid affecting survey counts.

Spotlight surveys

We used spotlight surveys (Whitworth & Carter 2014) to determine the number and distribution of *Synthliboramphus* murrelets in nearshore congregations at all four islands (Table 2). The three-person survey crew (i.e., boat driver, data recorder, spotlight observer) followed pre-determined GPS transects in an inflatable vessel and counted all murrelets observed in the spotlight beam. Spotlight surveys circumnavigated each island at roughly 150–

TABLE1
Summary of Craveri's (CRMU), Guadalupe (GUMU), and Scripps's (SCMU) murrelets captured at Islas San Roque, Cedros, and San Martín, Baja California, México during 2007–2008

Year	Island	Night	Time[a]	CRMU[b]	GUMU	SCMUb
2007	Cedros	6–7 April	20:55–01:15	9 (4)		2
2007	San Roque	8–9 April	23:55–00:55	6 (2)		
2008	San Martín	22–23 April	01:15–04:15	5 (3)	1	2 (1)

[a] Pacific Standard Time at Cedros and San Martín, Mountain Standard Time at San Roque.
[b] Numbers in parentheses indicate murrelets with brood patches.

300 m from shore depending on topography and navigation hazards such as submerged rocks and kelp beds. Round-island surveys were completed within one night on the shorter transects around San Roque (5.0 km), Asunción (5.5 km), and San Martín (9.1 km), but two nights (with two survey vessels on one night) were needed to complete the longer transect around Cedros (~110 km). It was usually not possible to identify murrelets to the species level, although some flying murrelets observed < 25 m away could be identified by: (1) the presence (CRMU) or absence (SCMU and GUMU) of a partial dark collar; or (2) the dark (CRMU) vs. white (SCMU and GUMU) underwing coverts.

We estimated the size of CRMU populations at each island using a spotlight survey correction factor that 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 per murrelet; 95% C.I. = 1.10–2.89; D.L.W. unpubl. data). The correction factor was determined using SCMU data from Santa Barbara Island, California—the only island where large samples of spotlight surveys have been conducted off a shoreline where most or all murrelet nests are accessible to researchers. Calculating correction factors has not been possible at other islands because large amounts of inaccessible breeding habitat have made it impossible to accurately determine the number of murrelet nests at islands where adequate samples of spotlight surveys have been conducted. For this study, we assumed that congregation behavior (and thus the correction factor) was similar for the closely related CRMU, SCMU, and GUMU. We applied this correction factor to the single round-island counts at Islas San Roque, Asunción, and Cedros, and the mean of two survey counts at Isla San Martín. The range of raw counts at San Roque, Asunción, and San Martín (Table 2) reflect exclusion (minimum) and inclusion (maximum) of unidentified small alcids observed during surveys. Unidentified alcids were either murrelets or Cassin's Auklets *Ptychoramphus aleuticus*, which also breed at all four islands. All murrelets observed at Asunción and San Roque were assumed to be CRMU (the only species captured at San Roque). Total spotlight counts at Cedros and San Martín were multiplied by the proportions of CRMU in the capture samples to obtain the adjusted counts for CRMU, which were then used to estimate breeding population size (Table 2). Limited data from Islas San Benito indicated that the proportions of SCMU and GUMU in samples captured at sea were very similar to the proportion of each species nesting on the island (Wolf *et al*. 2005, D.L.W. unpubl. data), but more studies are needed to confirm this relationship.

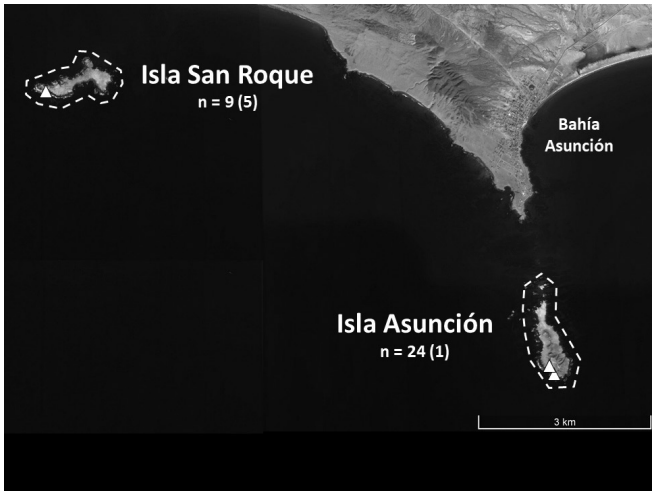

Fig. 2. Number of Craveri's Murrelets (unidentified alcids in parentheses) counted in coastal areas (indicated by white dashed transect lines) during nocturnal spotlight surveys at Islas San Roque and Asunción in 2007. White triangles indicate the location of Craveri's Murrelet nests found at each island.

Nest searches

We used hand-held flashlights to search for evidence of murrelet nests (i.e., incubating or brooding adults and chicks; and hatched, abandoned, or depredated eggs) in rock crevices, burrows, and under dense bushes. Searches were conducted at San Roque and Asunción on 8 April 2007, Cedros on 4 and 7 April 2007, and at San Martín on 12 April 2007 and 19 April 2008. Nest search crews accessed potential breeding areas by inflatable boat. San Roque,

TABLE 2
Summary of *Synthliboramphus* murrelets counted during nocturnal spotlight surveys conducted at islands off western Baja California, México during 2007–2008

Year	Island	Night	Time[a]	Total murrelets	CRMU %	Total CRMU[b]
2007	Cedros (East)	4–5 April	23:19–02:25	6	82%	5
	Cedros (West)	4–5 April	23:37–04:15	159	82%	130
	Cedros (South)	7–8 April	21:51–00:29	3	82%	2
	San Roque	8–9 April	22:50–23:34	9–14[c]	100%	9–14
	Asunción	8–9 April	01:40–02:15	24–25[c]	100%	24–25
2008	San Martín	19–20 April	00:23–01:42	58	63%	37
	San Martín	22–23 April	23:47–00:50	79–80[c]	63%	50

[a] Pacific Standard Time at Cedros and San Martin; Mountain Standard Time at Asunción and San Roque.
[b] Total counts were adjusted by the proportions of each murrelet species in the at-sea capture samples (see Table 1) to obtain an estimate for the number of Craveri's Murrelets (CRMU) at islas Cedros and San Martín.
[c] Upper end of range includes unidentified alcids.

Asunción, and San Martín required a single drop-off after which crews were able to access all suitable breeding habitats on foot, except for the cliffs at San Martín, which could not be searched. Access to areas searched on the northwest shore of Cedros required multiple drop-offs at the six shoreline areas and two offshore rocks deemed to be suitable murrelet breeding habitats safely accessible via inflatable boat. Genetic analysis of DNA isolated from eggshell membranes was used to determine species identity of seven CRMU eggs found during nest searches on Islas San Roque, Asunción, Cedros, and San Martín (Birt *et al*. 2008).

RESULTS

San Roque

We captured six murrelets at San Roque, all of which were CRMU and two (33%) of which displayed brood patches (Table 1). We counted 9 murrelets, 5 unidentified alcids, and 15 Cassin's Auklets around San Roque during the single spotlight survey (Table 2). Based on 100% CRMU in the capture sample and the fact no other murrelet species were observed or heard, all murrelets were assumed to be CRMU. Using a range of 9–14 CRMU from the spotlight count, the correction factor yielded 14–22 CRMU pairs (95% C.I. = 10–40 pairs).

We found one murrelet nest during the search of suitable breeding habitats in shoreline and upper-island areas at San Roque. The hatched murrelet eggshell found in a rocky area on the west side of the island (Fig. 2) was later confirmed as CRMU by DNA analysis. We also found 20 Cassin's Auklet crevices/burrows containing adults, chicks, or eggs, as well as a cache of 6–8 auklet carcasses in a shallow cave.

Asunción

We counted 24 murrelets and 1 unidentified alcid during the spotlight survey around Asunción (Table 2), but we did not attempt night-lighting captures to determine species composition. Based on 100% CRMU in the capture sample at nearby San Roque, we assumed that all murrelets counted at Asunción were CRMU. Using a range of 24–25 CRMU from the spotlight count, the correction factor yielded 38–40 CRMU pairs (95% C.I. = 26–72 pairs).

We found two murrelet nests during the search of suitable breeding habitats in shoreline and upper-island areas at Asunción. The murrelet eggs/eggshells found in two crevices at the back of rocky coves on the southwest shore (Fig. 2) were later identified as CRMU by DNA analysis. The first crevice contained an unbroken fresh egg and the other contained three broken eggs. Many suitable nest crevices were found in other shoreline coves, but upper island bluffs contained only a few marginal breeding sites in shallow crevices and under small bushes. We also found several recently occupied Cassin's Auklet burrows with fresh guano streaks at the entrance.

Cedros

We captured 11 murrelets at Cedros, including nine (82%) CRMU and two (18%) SCMU (Table 1). Four of nine (44%) CRMU, but neither SCMU, had brood patches. We counted 168 murrelets and 3 Cassin's auklets over two nights of spotlight surveys at Cedros (Table 2). Most (152; 90%) murrelets were distributed off the rugged north and northwest coasts (Fig. 3). In contrast, only 10 (6%) murrelets were found along the southwest shore around Cabo San Agustín, and six (4%) murrelets were found along the northeast coast (Fig. 3). Based on the proportions of CRMU and SCMU in the capture sample, adjusted spotlight counts yielded 138 CRMU and 30 SCMU in the overall survey total. Applying the correction factor to the adjusted CRMU count yielded 221 CRMU pairs (95% C.I. = 152–399 pairs).

We searched for murrelet nests in six shoreline areas and two offshore rocks on Cedros. Evidence of murrelet breeding consisted of three hatched eggshells, later confirmed as CRMU by DNA analysis, in two sites on the rocky northwest shore (Fig. 3). The first site contained a hatched eggshell found just outside the entrance of a crevice in a large rubble field at the base of a coastal cliff. The second site contained two hatched eggshells in a crevice under a large boulder at the base of a steep, dry ravine. The other four shoreline areas and two offshore rocks that we searched were described as "moderate" to "optimal" potential breeding habitats, with numerous suitable—but empty—nest crevices. We also found evidence of terrestrial predators; rodent feces were noted in both shoreline areas where murrelet eggshells were found, and a feral cat *Felis catus* carcass was found in another shoreline area at Punta Norte. A small Cassin's Auklet colony with more than 40 burrows, including one site with eggshell fragments, was found on an offshore rock near Punta Norte.

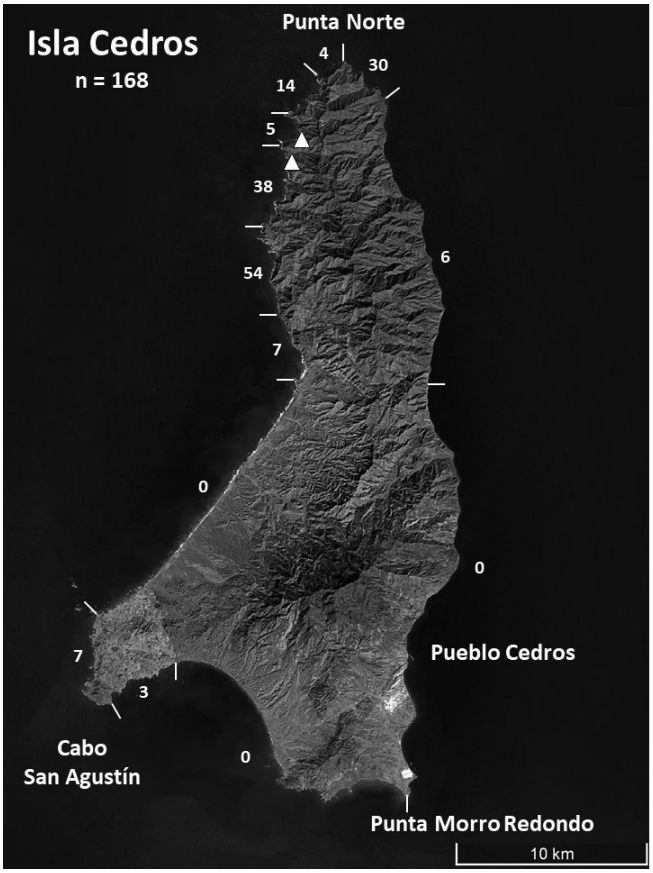

Fig. 3. Number of *Synthliboramphus* murrelets counted in discrete coastal areas (indicated by white boundaries) during nocturnal spotlight surveys at Isla Cedros in 2007. White triangles indicate the location of Craveri's Murrelet nests found on the northwest shore.

San Martín

We captured eight murrelets at San Martín, including five (63%) CRMU, two (25%) SCMU, and one (13%) GUMU (Table 1). Three (60%) CRMU and one (50%) SCMU had brood patches, but the lone GUMU did not. We counted 58 murrelets and 4 Cassin's Auklets during the spotlight survey on 19–20 April 2008, and 79 murrelets, 3 auklets, and 1 unidentified alcid on 22–23 April 2008 (Table 2). Most murrelets were distributed around the exposed western half of the island where the shoreline was composed of fragile, rocky cliffs (Fig. 4). The mean murrelet count for the two surveys was 69 (± 15 SD). Based on the proportions of each species in the capture sample, the adjusted mean spotlight counts yielded 43 CRMU, 17 SCMU, and nine GUMU in the overall survey total. Using the adjusted mean CRMU count, the correction factor yielded 69 CRMU pairs (95% C.I. = 47–124 pairs).

During 2007 nest searches, we found murrelet eggshells (later confirmed as CRMU by DNA analysis) in what was considered a "suitable nest site" located among shacks in the fishing village at Hassler Cove (Fig. 4). It was unclear at the time that this was an actual murrelet nest, although nests have been found in similar artificial habitats at fishing villages on Islas San Benitos and San Jerónimo (Keitt 2005, Wolf *et al*. 2005, D.L.W. unpubl. data). No other evidence of nesting, and only marginal breeding habitat, was found during searches in the fishing village and a short section of shoreline northwest of the village. During more extensive nest searches in 2008, we found no evidence of murrelet nesting in any of the accessible shoreline habitats around San Martín, although the most promising habitats on coastal cliffs were not searched. We found much evidence of Cassin's Auklets, including one egg in a burrow, many recently occupied burrows, and 19 auklet carcasses. Considering the amount of suitable auklet breeding habitat, we considered that the colony could potentially number in the "low thousands" of nests. However, we also found abundant evidence of snakes (e.g., molted skins and skeletons), which are potential predators of murrelet and auklet adults, eggs, and chicks.

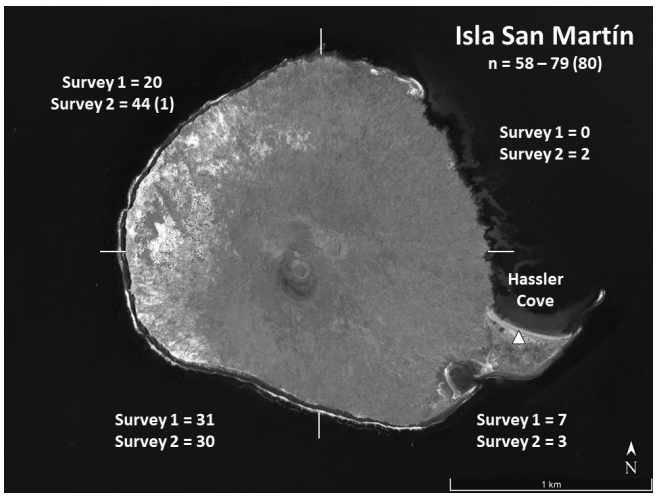

Fig. 4. Number of *Synthliboramphus* murrelets (unidentified alcids in parentheses) counted in discrete coastal areas (indicated by white boundaries) during nocturnal spotlight surveys at Isla San Martín on 19–20 April (survey 1) and 22–23 April (survey 2) in 2008. A white triangle indicates the location of Craveri's Murrelet eggshells found near Hassler Cove.

DISCUSSION

Past and current breeding at Asunción, San Roque, Cedros, and San Martín

Results of our surveys at Asunción, San Roque, Cedros, and San Martín have provided the first convincing evidence of breeding by CRMU (or any murrelet species) at these islands. The fact that breeding was not confirmed until 2007–2008 reflects the lack of surveys focused on murrelets at these islands, particularly Cedros, where our surveys were the first of any kind for this island. Historical reports of murrelets breeding at Asunción, San Roque, Cedros, and San Martín were limited to a few opportunistic observations and unsubstantiated speculation. Huey (1927) made no mention of murrelets during a visit to San Roque on 20 April 1927, but noted Cassin's Auklet burrows "everywhere in the soft soil on the top of the island." In contrast, Bancroft (1927) listed San Roque as a murrelet breeding location without any explanation other than he was "unable to state definitely to which species these belong." The only direct evidence of murrelet breeding for San Roque/Asunción was a reported Xantus's Murrelet egg and carcass collected at Asunción by R. Osorio in 1977 (Drost & Lewis 1995). Unfortunately, the current location of these specimens is unknown. Sympatric breeding by CRMU and SCMU has since been confirmed on San Roque and Asunción during nest monitoring by the Grupo de Ecología y Conservación de Islas (GECI) in 2014 (M. Félix pers. comm.). The lack of SCMU among the murrelets that we captured at San Roque/Asunción was probably due to the small sample captured during our single night of surveys in 2007. However, it is possible that SCMU had not yet recolonized these islands by 2007 following possible extirpation by introduced terrestrial predators in the mid-1900s (see below).

Kaeding (1905) reported Xantus's Murrelet as "fairly common on and about" San Martín, but made specific mention that "No specimens exhibiting the characters of *Brachyramphus craveri* (Salvad.) were noted, *craveri* being apparently confined to the Cape Region and Gulf of California." Wright (1913) also reported that Xantus's Murrelets were "heard each evening in the bay. Several sighted near-by on the way to San Quentin." These observations, however, were made on 5 July, well after the breeding season. A female CRMU (Natural History Museum of Los Angeles County [LACM] #51879) was collected on a boat at anchor off the south side of San Martín on 13 April 1951. Despite presumed murrelet breeding at San Martín, no nests had ever been found. By the mid-1970s, the lack of sightings at San Martín prompted Jehl & Bond (1975) to suggest that murrelets had likely been extirpated there (as well as at San Jerónimo and Natividad). There were no historical records or presumptions of breeding for any murrelet species at Cedros. Murrelets were not among the birds observed at Cedros in March–April 1906, but neither were murrelets observed at Natividad or San Benitos during this collecting trip (Thayer & Bangs 1907). The only murrelet record associated with Cedros was an adult male CRMU (LACM #50594) collected at sea off the "NW end" by G.P. Ashcraft on 27 February 1941.

Prior to our 2007–2008 surveys, the only standardized murrelet surveys in the region were conducted in 1999 when vocal call counts and nest searches were used to examine the status and distribution of murrelets at all islands except Cedros (Keitt 2005). Vocal surveys detected murrelets at San Martín (0–10 calls; n = 6 surveys, 21–23 April), but none at Asunción (n = 3 surveys, 3–4 March) or

San Roque (n = 4 surveys, 4–5 March). Furthermore, Keitt (2005) found no nests during searches at Asunción (8 h of searching), San Roque (6.5 h), and San Martín (4 h). The lack of murrelets at San Roque and Asunción in 1999 was somewhat surprising given the results of our surveys eight years later. At 27°N, the early March 1999 surveys should have occurred during the early to peak egg-laying period (Wolf *et al*. 2005) when many murrelets visit the at-sea congregation. If, as suspected, murrelets and Cassin's Auklets had been extirpated by introduced terrestrial predators at Asunción and San Roque sometime in the mid-1900s (McChesney & Tershy 1998), murrelets may not have yet recolonized either island by 1999 following the removal of non-native mammals in 1994 (Keitt 2005). We suspect murrelet populations were indeed extirpated at San Roque and Asunción because potential breeding habitats at both islands appeared easily accessible to terrestrial predators. In contrast, presumed extirpation of murrelets at San Martín (Jehl & Bond 1975) probably did not occur; we suspect a remnant murrelet population persisted in isolated cliff refuges that offered protection from terrestrial predators, but also made colony detection impossible without the use of focused survey techniques. In fact, the only murrelets detected at San Martín in 1999 were birds heard calling from at-sea congregations during vocal surveys (Keitt 2005).

We consider the consistent presence of *Synthliboramphus* murrelets in nocturnal at-sea congregations to be strong evidence of breeding on the adjacent island. In fact, we used congregations discovered at San Clemente, Santa Catalina, and San Miguel islands in California to target nest searches that resulted in the discovery of SCMU nests in previously undocumented breeding areas (Whitworth *et al*. 2014, 2018; Whitworth & Carter 2018a). However, with only one night each of captures at San Roque, Cedros, and San Martín, we could not establish the consistent presence (or absence) of any murrelet species in congregation waters at these islands. Fortunately, murrelet eggshells found at Asunción, San Roque, Cedros, and San Martín confirmed CRMU breeding. Genetic analysis was needed, however, to confirm species identity (Birt *et al*. 2008) because there are no visual or morphometric differences between CRMU, SCMU, and GUMU eggs (Bancroft 1930). The small numbers of SCMU captured at Cedros and San Martín indicated possible breeding by this species, but direct confirmation with active nests or eggs/eggshells will be very difficult to achieve given the rugged breeding habitats to be searched and the very small number of nests found to date. Thus, indirect confirmation with nearshore spotlight surveys and captures is the most plausible method for determining the breeding status of SCMU at Cedros and San Martín.

To our knowledge, the population estimates for Asunción, San Roque, Cedros, and San Martín are the first for any CRMU colony. However, these estimates at each island were based on just one or two spotlight surveys, which were probably conducted in the latter part of the murrelet breeding season based on observations of GUMU chicks at Isla Guadalupe in late March and early April 2007 (CIES, unpublished data). Thus, these should be considered preliminary population estimates until larger samples of surveys (preferably 6–8 per year at each island) can be completed. The preliminary estimates for San Martín (47–124 pairs) and Cedros (152–399 pairs) seem reasonable considering the large amount of potential breeding habitat on cliffs that offer protection from terrestrial predators still present on these islands. In contrast, CRMU populations at Asunción and San Roque are probably at the lower end of the estimated ranges for each island (26–72 and 10–40 pairs, respectively), as the upper end of these estimates seem higher than the available crevice habitat would indicate is possible, although murrelets at both islands may breed in vacant Cassin's Auklet burrows (e.g., San Miguel Island, California; Whitworth & Carter 2018a).

Historical breeding at other islands off west-central Baja California

Breeding by CRMU at Islas Asunción, San Roque, Cedros, and San Martín in 2007–2008 lent credence to presumptions of historical breeding at other islands off the west-central BC peninsula. CRMU breeding had long been suspected at Isla Natividad based on: (1) the purported collection of the CRMU type specimen by F. Craveri on 16 June 1857 (Fig. 5; Museo Zoologico Universita di Torino #645/5258; Salvadori 1865); (2) a presumed hybrid CRMU-SCMU individual (Jehl & Bond 1975) collected by A.W. Anthony on 6 April 1897 (Carnegie Museum of Natural History [CM] #P22965); and (3) a reported CRMU egg collected by H.A. Edwards on 8 May 1919 (California Academy of Sciences [CAS] #10043). While this evidence is indicative of CRMU breeding at Natividad, we have some doubts. For example, there was (and still is) considerable debate regarding the origin of the CRMU type specimen because the location was based solely on a note F. Craveri added to the margins of his travel journal (published in 1990; Craveri 1990) some years after his BC expeditions in

Fig. 5. Type specimen of Craveri's Murrelet (Salvadori 1865) stored at the Museo Zoologico Universita di Torino. "Golfo di California (Gulf of California)" is clearly written on the label despite the fact that this specimen was reported to have been collected at Isla Natividad.

1856–1857 (cf. Salvadori 1865, Bowen 2013). In fact, "Golfo di California (Gulf of California)" is written on the original museum label (Fig. 5). This issue is discussed at length by Cooke (1916), Jehl & Bond (1975), Violani & Boano (1990), and Bowen (2013). We do not consider any of the arguments for or against Natividad as the type location to be completely convincing and this question may never be fully resolved.

It is not known if the presumed hybrid CRMU-SCMU collected at Natividad in 1897 was taken on land or at sea, but this specimen raises obvious questions about the presence of both species at the island. The reported CRMU egg collected at Natividad in 1919 would seem to provide definitive evidence of breeding, but it is unclear how species identity was determined. Based on the collection date (8 May 1919) and a note that the egg was partially incubated ("inc ½"; L. Wilkinson, CAS, pers. comm.), it is doubtful that the egg was collected from an active nest where an incubating adult murrelet was observed. Rather, we suspect the egg was probably abandoned when found and species identity was assumed based on the belief that the CRMU type specimen was collected at Natividad. Genetic testing of this specimen would greatly assist our knowledge of historical CRMU breeding in west-central BC. Lamb (1927) reported Xantus's Murrelets as "numerous" and "generally in pairs" between Natividad and Cedros in December 1924 and January 1925, but made no mention of CRMU. Murrelets were not detected at Natividad during vocalization surveys and nest searches in 1999, but an adult CRMU was captured (and photographed) aboard an anchored boat on 6 May 1997 (Keitt 2005). Unfortunately, we did not survey murrelets at Natividad during 2007–2008. The recent discovery of an abandoned murrelet egg (species not determined) indicates that at least small numbers currently breed at Natividad (GECI, unpubl. data).

Historical breeding by CRMU has also been suspected at Islas San Benitos based on: (1) seven CRMU (Smithsonian Institution National Museum of Natural History #544024–544026 and #544034–544037) among 19 murrelets collected at night aboard an anchored vessel on 25 April 1968; and (2) five CRMU among 27 murrelets captured at night aboard an anchored vessel in late May 1971 (Jehl & Bond 1975). However, CRMU were not captured in a larger sample of 44 murrelets (n = 27 SCMU, n = 14 GUMU, n = 3 intermediate [*sensu* Jehl & Bond 1975]) at San Benitos on 27–29 March 2002 (D.L.W. unpubl. data). Nor were CRMU observed in nests found at San Benitos in 1999 (n = 28; Keitt 2005), 2003 (n = 25), and 2004 (n = 29; Wolf *et al*. 2005). However, CRMU have since been observed breeding sympatrically with SCMU and GUMU at San Benitos during nest monitoring by GECI (M. Félix, pers. comm). In retrospect, we cannot explain the absence of CRMU at San Benitos in 1999 and 2002–2004 given the previous observations in 1968 and 1971, and the later confirmation of nesting CRMU at San Benitos in 2014 and four other BC islands in 2007–2008.

CRMU breeding has never been suspected at Isla San Jerónimo, and we did not encounter them during spotlight surveys, at-sea captures, and nest searches there during 2007–2008 (CIES, unpubl. data). In fact, we were somewhat puzzled by the absence of CRMU in the large sample of 72 murrelets captured at San Jerónimo because this island lies just 80 km south of San Martín, and their absence implies a disjunct breeding distribution off west-central BC. A single CRMU was observed during the daytime just off San Jerónimo on 18 June 2015 (M. Félix pers. comm). As discussed above, we consider the presence of CRMU in nearshore nocturnal at-sea congregations to be a strong indicator of breeding, but this relatively late season at-sea observation during the daytime seems more indicative of visitation by post-breeding CRMU dispersing past San Jerónimo from other colonies. CRMU commonly disperse along the Pacific Coast of BC and California during the late spring to fall (van Rossem 1915, Jehl & Bond 1975, DeWeese & Anderson 1976). CRMU breeding has also never been suspected at Islas Los Coronados and Todos Santos off northwest BC. CRMU were not detected during extensive surveys (including spotlight surveys, at-sea captures, and nest searches) at Los Coronados in 2002 and 2005–2007, and Todos Santos in 2005 and 2007 (CIES, unpubl. data).

CONCLUSIONS

The first reliable documentation of CRMU breeding during our surveys at four islands off west-central BC in 2007–2008 indicated that we have much more to learn about the population size and distribution of *Synthliboramphus* murrelets in the region. Given the endangered status of all three murrelet species in México (SEMARNAT 2010), we recommend periodic monitoring (including spotlight surveys and at-sea captures) to determine the presence, size, and species composition of murrelet populations at breeding islands. Monitoring will be especially important where restoration efforts by GECI are currently underway to benefit seabird populations damaged by human impacts. The at-sea techniques that we used will be required to adequately assess the effectiveness of restoration actions for murrelets. Immediate management goals should include: (1) development of a rotating spotlight survey/at-sea capture monitoring plan so that all murrelet breeding islands are surveyed at minimum every five years; (2) determining the presence, size, and species composition of the murrelet population(s) at Natividad; and (3) focused survey efforts at Islas San Martín, Cedros, and San Benitos, where sympatric breeding by two or three murrelet species may occur.

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