
STATUS OF THE CALIFORNIA RED-LEGGED FROG (*RANA DRAYTONII*) IN THE STATE OF BAJA CALIFORNIA, MÉXICO

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Abstract.—The California Red-legged Frog (*Rana draytonii*) is a threatened species in the United States that has undergone population declines, especially in southern California. Due to the lack of information on the status of Mexican populations, we surveyed for the presence of *R. draytonii* in Baja California and assessed possible threats to population persistence. Our study area extended from the U.S.-Mexican border to the southern end of the distribution of the species in the Sierra San Pedro Mártir. We found *R. draytonii* at six of 15 historical sites, none at five proxy sites (i.e., alternative sites chosen because the historical record lacked precise locality data), and four at 24 additional sites. The 10 occupied sites are within three watersheds in the Sierra San Pedro Mártir (two sites at Arroyo San Rafael, two sites at Arroyo San Telmo, and six sites at Arroyo Santo Domingo). We did not detect *R. draytonii* at 60% of historical sites, including the highest elevation site at La Encantada and multiple low-elevation coastal drainages, suggesting the species has declined in Baja California. The threats we noted most frequently were presence of exotic aquatic animal species, water diversion, and cattle grazing. Management of remaining populations and local education is needed to prevent further declines.

Key Words.—amphibians; conservation; exotic species; San Pedro Mártir

INTRODUCTION

The California Red-legged Frog (*Rana draytonii*) is the largest native frog in western North America. Historically, this species ranged from Mendocino County and the foothills of the Sierra Nevada in northern California, USA, to near Arroyo Santo Domingo along the western slopes of the Sierra San Pedro Mártir, Baja California, México (Fellers 2005). However, overharvesting in the late 1800s and early 1900s, the introduction of non-native predators, habitat loss and disturbance, and the use of pesticides have contributed to its disappearance from an estimated 70% of its range in California (Jennings and Hayes 1994; Fisher and Shaffer 1996; Richmond et al. 2014). These factors led to the listing of the species as Threatened under the federal Endangered Species Act in 2002 (U.S. Fish and Wildlife Service [USFWS] 2002). While a great amount of attention has been given to *R. draytonii* in California, information on its status in México is sparse.

In Baja California, *R. draytonii* has been documented at 21 sites (Appendix Table 1). Welsh (1988) reported *R. draytonii* at 10 locations in the Sierra San Pedro Mártir, from near sea level to 2,200 m elevation, and

regarded the species as abundant in riparian habitats. More recently, Krofta (2003) reported on *R. draytonii* in the Arroyo San Telmo and Arroyo Santo Domingo, and Fidenci (2004) provided photo vouchers of *R. draytonii* at two localities in the foothills of the Arroyo Santo Domingo. Both Krofta (2003) and Fidenci (2004) regarded the populations in the Arroyo Santo Domingo to be sizable and possibly the largest remaining populations in México. At higher elevations, a specimen collected in the mountain meadow at La Grulla (2,100 m elevation) in 2006 (catalog # UABC 1650; Appendix Table 1) confirms the recent presence of *R. draytonii* in the upper Santo Domingo watershed. Relatively little information is available for the status of *R. draytonii* between the Sierra San Pedro Mártir and U.S.-Mexican border, with only five historical records dating between 1905 and 1978 (Appendix Table 1).

In this study, we report on the status of *R. draytonii* across the historical range in Baja California and identify potential conservation threats. We review data on historical occurrence of *R. draytonii* and report results of recent field surveys, including assessments of previously documented localities. This study provides baseline data for managing and protecting the species in México, and

documents changes in the southernmost portion of the range of the species.

MATERIALS AND METHODS

Study area.—We conducted our study in Baja California, from the United States–México border to approximately 250 km south in the vicinity of San Quintín, and from the Pacific Ocean coastline to 80–100 km east into higher elevations of the Sierra Juárez and Sierra San Pedro Mártir. This region includes Mediterranean California floristic components and coniferous forest at higher elevations (Delgadillo-Rodríguez 1998). Mean annual precipitation for the state in 2013 averaged 193.8 mm, and in 2014 only 85.1 mm (mean state precipitation: 200 mm, CONAGUA 2014). We selected survey sites by searching for *R. draytonii* locality records in online databases (<http://www.herpnet.org> [Accessed 26 January 2013]), the herpetological collection records at the Universidad Autónoma de Baja California in Ensenada, Baja California (UABC), and published literature (Welsh 1988; Grismer 2002; Kofka 2003; Fidenci 2004). We also included habitats where large ponds within a main stream were visible on satellite images on Google Earth (2006–2011 imagery, <http://earth.google.com>, last accessed on July 2013), located within the general distribution of the species. We assigned coordinates to locality records lacking specific geo-referenced locations, depending on the quality of the original locality description, following the point-radius method (Wieczorek et al. 2004). We considered records within 3 km to represent the same locality. For historical locations containing little specific information, we identified proxy sites within the general area and selected survey sites with characteristic frog habitat.

Surveys.—We focused our surveys on streams and pools with permanent water as well as off-channel ponds, wetlands, and riparian zones. Adult *R. draytonii* are often associated with perennial or intermittent streams that flow through dense, shrubby, woody vegetation. Occupied streams usually have areas of deep pools (> 0.7 m), still or slow-moving water, and emergent vegetation, including *Typha domingensis*, *Schoenoplectus californicus*, and *Salix* spp. (Jennings and Hayes 1994; Alvarez et al. 2013). Metamorphs are also found in areas with limited vegetation and shallow water (Hayes and Jennings 1985).

We conducted surveys from March to July 2013 and from February to June 2014. Day and night visual encounter surveys (Heyer et al. 1994) included all microhabitats likely to be used by *R. draytonii* (water surface, moist vegetation and leaf litter, stream banks near pools). We estimated the total survey length (in Appendix Table 2) by measuring the stream path

travelled using a global positioning system (GPS). We visited all sites at least once, although not all visits resulted in a formal survey effort. A second visit was made only at locations where we detected frogs or at sites without frogs but the habitat appeared appropriate during our first visit. Appendix Table 2 indicates the number of days and nights spent at each site and each visit (2013 or/and 2014); replicate surveys within the day are not included because they varied depending on available habitat at each site (range: 1–3 per day). We captured, marked, and released frogs after we recorded gender, length, and mass. We recorded each frog location with a handheld GPS. We swabbed the skin for chytrid fungus using the protocol of Hyatt et al. (2007) and excised a small tissue sample for DNA analysis (results reported elsewhere). At each site, we searched for exotic species implicated in declines of *R. draytonii* (and other anurans), such as Green Sunfish (*Lepomis cyanellus*), American Bullfrogs (*Lithobates catesbeianus*) and Red Swamp Crayfish (*Procambarus clarkii*). We noted the presence of San Pedro Mártir Rainbow Trout (*Oncorhynchus mykiss nelsoni*), which is native to a 24 km stretch in Arroyo San Antonio in the Santo Domingo watershed (Evermann 1908; Ruiz-Campos et al. 2014). This species has also been introduced to Arroyo San Rafael, Valladares, La Zanja, La Víbora, and La Grulla on several occasions from 1929 to 1941 (Ruiz-Campos and Pister 1995; Ruiz-Campos et al. 2014). We also documented activities with potential to disturb habitat such as livestock presence (animals or tracks of cows, goats, horses, or donkeys), human recreation (site used as a swimming hole or off-road trails), and pumps for water extraction.

We present survey results and site descriptions from north to south. Sites are grouped by watershed. Site numbers in our descriptions correspond to those in Appendix Table 2 and Figure 1. We present descriptions of our additional sites (i.e., sites within our study area but where we found no historical records of *R. draytonii*) at the end of the Results section. We refer to native species by their scientific name, and non-native species by their common name.

RESULTS

We were able to locate historical sites with high confidence for most records; however, five lacked precise locality data, so we surveyed a nearby proxy site instead. We visited 15 historical, five proxy, and 24 additional sites. We surveyed only 40 of these sites because four historical sites lacked suitable habitat (i.e., no surface water present; Appendix Table 2). Our surveys covered a total of 60 km of stream-associated habitats (average 1.5 km per survey). We observed *R. draytonii* at 10 sites; six of these were historical and four

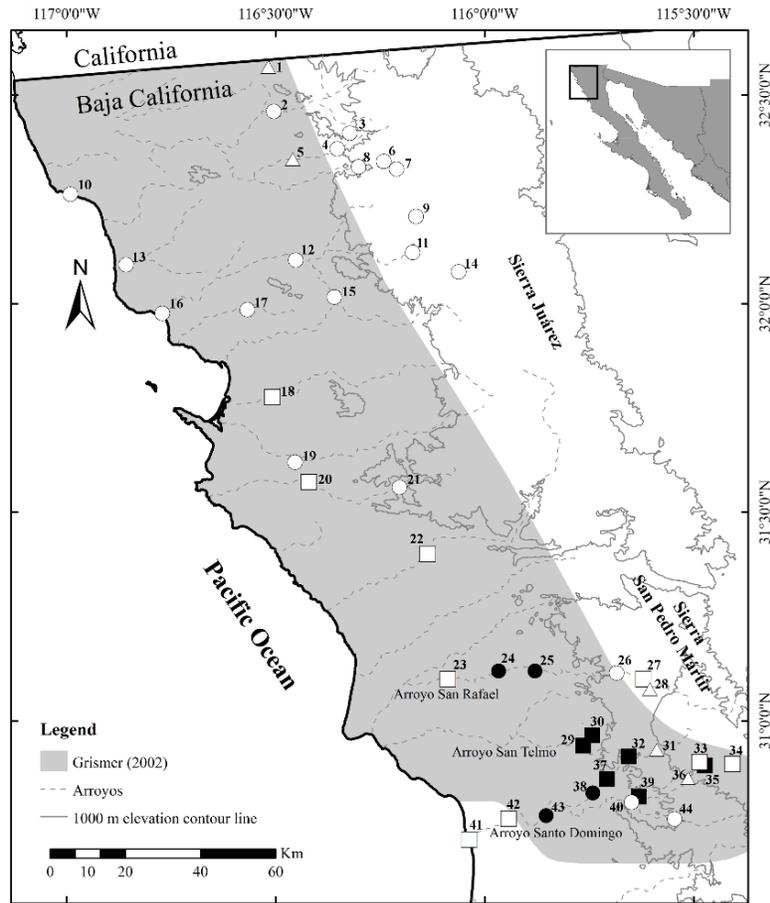


Figure 1. Location of survey sites for California Red-legged Frogs (*Rana draytonii*) in Baja California, México. Numbers correspond to Appendix Table 2. Symbols are □ = historical sites with no detection of *R. draytonii*; ■ = historical site with presence of *R. draytonii*; △ = proxy site (alternative sites chosen because the historical record lacked precise locality data) with no detection of *R. draytonii*; ○ = additional sites with no *R. draytonii*; • = additional sites with presence of *R. draytonii*. Distribution of *R. draytonii* is shown in grey based on Grismer (2002).

were additional. Locations where we found *R. draytonii* are all within three watersheds of the Sierra San Pedro Mártir: San Rafael (sites 24–25); San Telmo (sites 29–30); and Santo Domingo (sites 32, 35, 37–39, 43). We collected data from 156 adults, 40 subadults, and 15 metamorphs (Table 1). We detected frogs within the first survey day at all occupied sites except for site 25 in Arroyo San Rafael, where *R. draytonii* was detected on the third survey day.

Tijuana watershed.—Rancho Las Dos Cumbres, Arroyo Tecate (site 01). *Rana draytonii* has been recorded historically from Tecate (Appendix Table 1), which is now a sprawling city. We surveyed a proxy site, a location in Arroyo Tecate with permanent running water, located 10 km east of the city. This is a narrow

stream (< 1 m) in oak (*Quercus* sp.) forest with scarce emergent vegetation, shallow water (< 10 cm), and few stream pools (approximately three pools, < 80 cm deep). We did not find *R. draytonii* and the stream appeared to have too little water to support adult frogs. A few shallow pools (0.2 m) had egg masses of Baja California Treefrog (*Pseudacris hypochondriaca*) and Western Toad (*Anaxyrus boreas*). We found Red Swamp Crayfish in all stream pools.

Arroyo Las Palmas: Arroyo Las Calabazas (sites 05, 07, 08). The historical record indicates a site approximately 32 km south of Tecate (Appendix Table 1). Two streams converge in this area: Arroyo Las Palmas and Arroyo Las Calabazas. Floodplains of both streams are now cultivated with crops and

Herpetological Conservation and Biology

TABLE 1. Number of captures and mean sizes (snout-vent length and mass) of California Red-legged Frogs (*Rana draytonii*) in Baja California, México, 2013–2014. The number of surveys for each site are in Appendix Table 2. Abbreviations are AF = adult females; AM = adult males; Sa = subadults; M = metamorphs.

Locality	Captures						SVL (mm)				Mass (g)			
	2013	2014	AF	AM	Sa	M	AF	AM	Sa	M	AF	AM	Sa	M
23 km east of Colonet	11	7	2	3	2	11	105.5	83.6	54.5	28	110.5	55.3	16.2	2.5
32 km east of Colonet	-	1	0	0	1	0	-	-	-	-	-	-	-	-
Rancho Meling, Arroyo San José	9	9	5	10	3	0	94	78.1	60.3	-	86.4	48.8	26.5	-
Rancho El Molino, Arroyo San José	1	-	0	1	0	0	-	84	-	-	-	76	-	-
Rancho El Potrero	7	4	2	9	0	0	107	89.5	-	-	104	67.3	-	-
La Grulla, Sierra San Pedro Mártir	77	60	54	57	26	0	93.7	82.5	57.5	-	90.2	60.8	23.4	-
Rancho Valladares	5	1	1	1	3	0	98	73	51.6	-	65	34	12.6	-
7.5 km S from Rancho Valladares	-	3	1	2	0	0	88	91	-	-	61	-	-	-
Rancho San Antonio	6	8	2	6	6	0	82	80.5	52	47.2	52	45.5	13.7	10.8
2 km S of Rancho La Canastilla	4	-	0	0	0	4	-	-	-	28.2	-	-	-	2.2

there is no permanent surface water. We searched upstream in both arroyos until we found a reach with permanent surface water. We surveyed a proxy site at Arroyo Las Palmas (site 05; approximately 28 km south of Tecate); 90% of the 5-km stretch was heavily disturbed by off-road vehicles. A fenced stretch of the arroyo (about 200 m) had intact cottonwood (*Populus* sp.) forest lining a narrow, deep stream. There were two pools (0.5–1.5 m deep) with slow-moving water and abundant aquatic vegetation. We did not find *R. draytonii*. We surveyed Arroyo Las Calabazas at two sites separated by 13 km (36 km [site 07] and 43 km [site 08] southwest of Tecate). We found several pools with rocky substrate and low surface flow. We found no *R. draytonii*, and both sites had Red Swamp Crayfish.

Maneadero watershed.—San Carlos Canyon, 11.8 km east of Highway 1 (site 18). At this location, the stream passes through oak forest and has a series of deep pools with slow running water. There are also many ponds created by small human-made dams in the stream channel. We surveyed three stretches of the stream each of which was about 600 m. We did not find *R. draytonii*. Exotic species were abundant throughout, including Mosquito Fish (*Gambusia affinis*), American Bullfrog, Green Sunfish, and Red Swamp Crayfish.

Santo Tomás watershed.—Santo Tomás (site 20). Historical location is recorded as San Tomás (= Santo Tomás Town, Goldman 1951, Appendix Table 1). Floodplains around San Tomás are now mostly vineyards with scattered riparian vegetation and surface water only during the rainy season. We surveyed the nearest reach of the stream with permanent water (20 km upstream of Santo Tomás) at Rancho Agua Caliente (site 21). Habitat in this area appeared suitable for frogs, with undisturbed riparian vegetation, large and deep pools (< 1 m), a wide stream (about 3 m), and abundant emergent

and submerged aquatic vegetation. We did not find *R. draytonii*. We saw abundant Green Sunfish throughout the creek. According to the property owner, deeper swimming holes were used for recreation in the past, but access is now restricted (Rigoberto Zuñiga [Rancho Las Águilas], pers. comm.).

San Vicente watershed.—19.3 km east of San Vicente (site 22). We conducted this survey approximately 15 km east of San Vicente at arroyo Agua Caliente, walking 5 km upstream and 2 km downstream. The habitat consisted mainly of open, shallow water with sandy bottoms. We located three deep ponds (0.5 m) covered with aquatic vegetation. We did not find *R. draytonii*. Red Swamp Crayfish were once common but disappeared after heavy rains and flooding in 2010 (Rolando Arce, pers. comm.). We found Mosquito Fish throughout the survey area.

San Rafael watershed.—Ejido Benito Juárez (site 23). Grismer (2002) has a photograph of an adult frog from Ejido Benito Juárez at 11 km east of Colonet (BDH, unpubl. data). The floodplain of the stream is now cultivated with crops, with surface water present for only a short time after heavy rains (Roberto Gonzalez, pers. comm.). We surveyed a stream reach with permanent water at 23 km and about 32 km upstream of Colonet (sites 24 and 25, respectively). In both reaches, the stream is narrow (< 1.2 m) and shallow (< 12 cm) with abundant streamside shrubs (*Salix lasiolepis* and *Baccharis* sp.) and an open canopy. Site 24 was surveyed in 2013 and 2014. In the first year, we found 11 metamorph *R. draytonii*. Most of the metamorphs were basking on aquatic macrophytes (*Azolla* sp.) that covered the sides of the main channel. In 2014, we found five adults in a human-made pond (about 1.5 m deep) associated with adjacent agricultural fields, including a calling male, and two subadults in the stream

near the pond. At site 25, we observed one subadult *R. draytonii* at night on the stream bank among willows that evaded capture.

Rancho Mike's (sites 26, 27, and 28). Several specimens (adults and larvae) have been collected or observed at or near this site (see Appendix Table 1). We surveyed a 0.55 km stretch downstream (site 26) from Mike's Sky Ranch, and longer reaches of 4.3 and 1.0 km upstream of the Ranch (sites 27, 28). Rains had released silt into portions of the stream near site 27 following a fire in July 2012. In 2013, unburned areas contained a wide stream (< 3 m) in an oak forest with both rocky and sandy bottoms, abundant emergent vegetation, and shallow and deep pools (< 1.5 m). We did not find *R. draytonii*. Human disturbance was concentrated in camping areas. San Pedro Mártir Rainbow Trout were common throughout the survey area.

San Telmo watershed.—Rancho Meling (=San José), Arroyo San José (site 29). We surveyed the stream at 1.5 km downstream of Rancho Meling. We found frogs in three adjacent human-made ponds 160 m east of the main channel (surface areas = 1,648 m², 600 m², and 400 m²). All ponds had aquatic vegetation and were surrounded by *Quercus agrifolia* and *Populus fremontii* trees. Over four surveys in 2013 and 2014, we captured 15 adult and three subadult *R. draytonii* in the two largest ponds and no frogs in the smallest pond. An adult male *R. draytonii* was calling in the largest pond during our 2013 survey.

Rancho El Molino (site 30). At this site, located 5 km downstream of Rancho Meling, the stream contained a mixture of wide, shallow, sandy areas and narrow, deep, rocky pools. About 1.0 km downstream of the ranch, the gradient increased and water flowed into several plunge pools. Several deep side pools with aquatic vegetation were adjacent to the main channel. We captured one adult male *R. draytonii* in a dense stand of Arroyo Willow (*S. lasiolepis*) in a wetland adjacent to the main stream.

Santo Domingo watershed.—La Jolla (site 31). From the coordinates provided in Welsh (1988), it is likely that this location refers to Cañón La Jolla (= Arroyo La Corona) near its confluence with Arroyo La Tasajera and Arroyo La Canoa. The three drainages join to form Arroyo El Potrero. We surveyed at and around this confluence, as well as in the downstream section of El Potrero. At the time of the surveys, Cañón La Jolla had a small amount of flowing water and no deep ponds or pools. At the confluence, La Tasajera contained large ponds covered with aquatic vegetation, but only a small amount of flowing water. Arroyo La Canoa had fast running water that cascaded through a rocky streambed. Downstream, Arroyo El Potrero contained a wider streambed with a mix of rocky cascades, pools, and side

channels. We did not find *R. draytonii* or any exotic species.

Rancho El Potrero (site 32). This site is located downstream of La Jolla. We surveyed a stretch of arroyo El Potrero with a rocky bottom that contained both shallow and deep sections, with some stretches covered with aquatic vegetation. We captured 11 adult *R. draytonii* and saw one subadult and one egg mass. Adult frogs were in a small oxbow pond (surface area = 70 m²) six meters from the main channel. The pond water was turbid, with felled logs, overhanging willows, and scarce aquatic vegetation. The subadult was basking on a rock in the main stream channel. The egg mass was attached to floating aquatic vegetation in slow-moving water, also in the main stream channel. We observed 12–15 San Pedro Mártir Rainbow Trout in the main channel downstream from the oxbow pond.

Rancho Viejo (site 33). Sightings were made by Welsh (1988), but the specific location is unknown. The site is a montane meadow surrounded by coniferous forest. We surveyed the main stream channel of Rancho Viejo that contained surface water, from the middle of the meadow to its confluence with Arroyo La Grulla, approximately 2.5 km downstream. The meadow and arroyo had shallow running water (< 10 cm) with a sandy bottom, but no evidence of deeper ponds that might be suitable for breeding. We did not find *R. draytonii* and saw many juvenile San Pedro Mártir Rainbow Trout.

La Encantada (site 34). This site is a large mountain meadow surrounded by coniferous forest. We found an unvegetated stream channel (about 1 m deep and about 1 km long) with no flowing water. However, some standing water was present in the channel (about 25 cm, with some areas reaching 60 cm) at the time of our survey. Historical accounts from 1796 (Minnich and Franco-Vizcaíno 1998) indicated the presence of marshy habitat with a deep pond in the meadow. Local ranchers recounted the presence of a large pond or lake in the area about 50 y ago (Rolando Arce, pers. comm.), but no marshy habitat or ponds exist today. We found no *R. draytonii*. About 500 cows were grazing in the meadow during our survey.

La Grulla (site 35). This site is a large mountain meadow downstream of La Encantada and surrounded by coniferous forest. The meadow contains a complex of ponds and sinkholes along its western edge that eventually flow into a channel downstream where the water descends through multiple rocky pools before becoming a stream flowing through the pine forest. During two visits, we captured 137 *Rana draytonii* (111 adults and 26 subadults). We found most frogs near the shore of two ponds. The largest meadow pond was approximately 2–3 m deep and contained over 100 *R. draytonii* tadpoles. The ponds were covered with aquatic vegetation, mostly Floating-leaf Pondweed

(*Potamogeton natans*), and surrounded by a grassy wetland. We saw no frogs beyond 50 m downstream from the edge of the meadow, where the San Pedro Mártir Rainbow Trout were abundant. We saw no trout in any ponds in the meadow.

Arroyo La Vibora (site 36). Welsh (1988) observed frogs at the top of Arroyo San Antonio, corresponding to Arroyo La Vibora. This arroyo contains large boulders on a rocky streambed, with sporadic emergent vegetation. There were many pools (1–4 m², < 3.5 m deep) within the stream. We did not find *R. draytonii*. We saw 30–50 San Pedro Mártir Rainbow Trout in the pools.

Rancho Valladares (sites 37 and 38). At Rancho Valladares (site 37), the site had shallow running water over open sandy areas, with ponds located adjacent to the main channel. Vegetation around the ponds was mainly *S. lasiolepis*. We captured two adult and three subadult *R. draytonii* in one small off-channel pond (11 m²). We did not find any frogs in eight larger ponds in the stream reach. At site 38, located 7.5 km downstream of Rancho Valladares, we surveyed a 3-km stretch of stream habitat. The stream passes through rocky substrate with abundant riparian vegetation and contains a series of plunge and side pools. Several (about six) side ponds (about 4–6 m²) contained no open water and appeared to have been filled with sediment and large stands of dry Southern Cattails (*Typha domingensis*). We captured four adult *R. draytonii* within the stream: one underneath a boulder and three within a dense stand of *S. lasiolepis*. One subadult evaded capture. We did not see any exotic species.

Rancho San Antonio (site 39). Our survey reach had slow-moving water with deep, large pools and abundant aquatic and riparian vegetation such as Mule-fat (*Baccharis salicifolia*), Western Sycamore (*Platanus racemosa*), and *S. lasiolepis*. We captured nine adults, six subadults, and one tadpole of *R. draytonii* in pools within or along the main stream (on rocks, shoreline, and in floodplain vegetation). We observed San Pedro Mártir Rainbow Trout throughout this area and this is the only survey site where the trout is native. We did not see any exotics.

San Ramón, mouth of Arroyo Santo Domingo (site 41), and 5.95 km east of Colonia Guerrero, near Misión Santo Domingo (site 42). These historical sites in the lower part of the Santo Domingo no longer have perennial surface water, except during heavy rains. We observed numerous water extraction pumps located within the arroyo. We surveyed upstream until we found surface water, which began at a location approximately 15 km above the mission and 2.0 km south of Rancho La Canastilla (site 43). At the time of our survey there was no flowing water, but the stream channel contained both shallow and deep rocky ponds with abundant cattails (*Typha* sp.). We captured four metamorph *R. draytonii*

during the day. We saw one frog basking on top of aquatic vegetation near the edge of a pond, one on the grassy shore of an adjacent small pond, and two crossing a cattail wetland. We observed Green Sunfish in all ponds. This was the only locality where we found both *R. draytonii* and an exotic species.

Additional localities.—We surveyed 16 additional localities with no previous records of *R. draytonii*. We did not find *R. draytonii* at any of these sites (02–04, 06, 09–17, 19, 40, 44; Appendix Table 2). We found habitat that appeared suitable for *R. draytonii* at nine of these additional sites (04, 09, 11–15, 17, 44). We detected exotic species at 10 sites (sites 02, 04, 06, 09–10, 12–13, 15, 17, 19; average 1.2 species per site, range 1–5), including Red Swamp Crayfish, Green Sunfish, Mosquito Fish, Black Bullhead (*Ameiurus melas*), American Bullfrogs, African Clawed Frogs (*Xenopus laevis*), and Red-eared Sliders (*Trachemys scripta*). Thirteen of these localities were commonly used for recreation (sites 02–04, 06, 09–15, 17, 19) and water extraction (sites 02–04, 06, 09, 11–17, 19). Ten sites showed signs of livestock use (sites 02–04, 06, 09, 11, 14, 17, 19, 44).

DISCUSSION

We detected *R. draytonii* at 10 of 44 sites sampled across their historical range in Baja California, with evidence of breeding (egg masses, tadpoles, or metamorphs) at five sites (24, 32, 35, 39, 43). Although our survey efforts indicate that the species probably does not occur outside of the Sierra San Pedro Mártir, the persistence of populations within the Sierra San Pedro Mártir represents a positive development for conservationists working to prevent the extirpation of the species in México.

From the U.S.-Mexican border to Arroyo San Vicente, we found that *R. draytonii* is absent from 22 localities, including five with historical records. While 13 of these 22 localities have suitable breeding habitat, 16 have exotic species and other potential threats (Appendix Table 2). Our lack of detection of *R. draytonii* may not equate to their absence, particularly in cases where we conducted only a single survey. However, most locations are small and could be thoroughly surveyed. At nine of 10 sites where we found *R. draytonii*, we found the species on the first survey. Lack of detection might indicate population extirpations, or that numbers of individuals are so low in certain areas that our sampling technique was insufficient to detect them. Regardless, these observations all suggest that *R. draytonii* has experienced population declines in the northernmost parts of Baja California.

The bulk of historical records for *R. draytonii* in Baja California are from the Sierra San Pedro Mártir, where

the species was considered abundant as recently as the early 1980s (Welsh 1988). Our surveys failed to detect frogs at nine historic locations, six of which had sufficient detail in the record to give us confidence that we surveyed the correct locality: Ejido Benito Juárez, Rancho Mike's Sky, Rancho Viejo, La Encantada, San Ramón, and 3.95 km east of Colonia Guerrero. Water extraction at the first and last two locations exceeds the mean annual recharge volume, so surface water is no longer present (SEMARNAT 2015). Numerous water extraction pumps are located within the arroyos (> 60 pumps in a 20-km stream reach for Ejido Benito Juárez, pers. obs.), mostly for agricultural purposes (Roberto González, pers. comm.). In May 2002 and May 2003, Fidenci (2004) surveyed downstream from Misión Santo Domingo and found *R. draytonii* tadpoles, but no adults. During our survey in July 2013, this area was dry and local residents reported that the stream flows only during heavy rains. We found metamorphs 12.5 km upstream from the location surveyed by Fidenci (2004). At middle elevation sites surveyed by Fidenci (2004), we also found *R. draytonii* at Rancho El Potrero (although in low numbers). At Valladares, we found a few frogs in small ponds adjacent to the main channel, whereas Fidenci (2004) found no frogs. It is possible that *R. draytonii* use the Valladares area as a dispersal corridor during wetter parts of the year, given that the ponds in this section of the arroyo dry up during the summer. The last *R. draytonii* from La Encantada, the highest elevation site recorded in Baja California, were reported by Welsh (1988) from 1974. The most recent vouchered specimens from the site are from 8 July 1945 (catalog #SDNHM 36457, Appendix Table 1). In 1923, 113 specimens (tadpoles and adults) were collected from this same site (CAS collection, Appendix Table 1). Today, the habitat consists of a bare meadow and a channelized stream, and *R. draytonii* appears extirpated.

Conservation threats.—At least one conservation threat was evident at all sites, although we found slightly fewer threats at sites where we detected *R. draytonii* (mean 2.0) versus sites where we did not (mean 2.4; Appendix Table 2). From the U.S.-Mexican border to Arroyo San Vicente (sites 1–22), we found water extraction at 19 sites, human recreation at 18 sites, exotic species at 16 sites, and livestock at 14 sites. In the Sierra San Pedro Mártir (site 23–44), livestock were present at 14 sites, water extraction at nine sites, translocated trout at six sites, recreation at five, and exotics at one.

Local ranchers have introduced exotic species, such as Red Swamp Crayfish and Green Sunfish, and in some cases protect them to avoid over-harvesting (APG and JHVV, pers. obs.; sites 06–09, 14). Some introduced species in the northern part of our study area (i.e., American Bullfrogs, Mosquito Fish, Green Sunfish) are known to adversely affect native amphibians, including

R. draytonii (Lawler et al. 1998; Riley et al. 2005; Cruz et al. 2006). In the Sierra San Pedro Mártir, only one site in the lower Santo Domingo watershed (2 km south of Rancho La Canastilla) has *R. draytonii* co-existing with an exotic species, the Green Sunfish. In addition, little is known about the ecological effects of translocated San Pedro Mártir Rainbow Trout in the San Rafael watershed, and into higher elevation sites upstream of its native range in the Santo Domingo watershed. Neither of two studies on trout stomach contents found *R. draytonii* as prey items in Arroyo La Grulla (Cirilo-Sánchez and Ruiz-Campos 1987; Ruiz-Campos 1993) and Arroyo San Rafael (Ruiz-Campos and Cota-Serrano 1992). In California, introduced trout are known to have adverse effects on the Sierra Nevada Yellow-legged Frog (*Rana sierrae*) and the Southern Mountain Yellow-legged Frog (*R. muscosa*; Vredenburg 2004; Knapp et al. 2007).

Water extraction for domestic and agricultural consumption has noticeably affected the hydrology of watersheds. Four historical coastal sites no longer have surface flow (Santo Tomás, Ejido Benito Juárez, 3.95 km east of Colonia Guerrero, and San Ramón) and dewatering persists for several kilometers upstream. At these locations, wells, pumps, and a network of surface pipes exist throughout the area. In Arroyo San Rafael, we located the first signs of surface water at 38 km upstream. In a 10 km stretch of the stream, we located only two pools with sufficient water to support amphibian breeding, and agricultural fields are located immediately adjacent to the arroyo. Similar situations can be found in Arroyo San Telmo and Arroyo Santo Domingo. Interviews with local ranchers indicate that after the arrival of large agricultural enterprises in 1998, downstream water sources began to dry up and large ponds with frogs disappeared. The Mexican National Water Commission determined that 14 aquifers in our study area are currently overexploited, with some beginning to experience salinization (CONAGUA 2014). Our findings suggest that *R. draytonii* might be in greatest jeopardy in low elevation localities because the sites appear to contain small numbers of frogs and water is more easily extracted (sites 24 and 43).

Presence of livestock in and around streams can have adverse effects on habitat quality for some riparian wildlife, including soil compaction, loss of bank stability, reduced water retention, increased sediment load, increased water temperature, and a decrease in depth and amount of native vegetation around breeding pools (Kaufman and Kreuger 1984; Orodho et al. 1990; Fleischner 1994; Li et al. 1994; Sidle and Sharma 1996). Studies in the Sierra San Pedro Mártir National Park indicate that soil compaction reduces water infiltration to the phreatic zone, which promotes desertification of mountain meadows (CONANP 2006). Livestock records date to 1796 and indicate that an average of

6,000 cattle grazed annually in the Sierra San Pedro Mártir National Park from 1924–1960 (Delgadillo-Rodríguez 2004). One example of damage caused by livestock grazing is at La Encantada, where *R. draytonii* and suitable habitat for the species were once abundant. Interviews with ranchers indicate that approximately 500 cattle grazed at the time of our visit in June 2013 in the La Encantada meadow. The same threats exist for La Grulla meadow, which contains the largest number of frogs recorded in the survey. The degree to which this population is affected by livestock is unknown, as there are no census or trend data for *R. draytonii* at the site. Because the meadow is grazed only in the warmer months (CONANP 2006), the ecosystem may have time to rehabilitate seasonally, or the number of cattle at any given time might be below a threshold that would more acutely affect *R. draytonii*. The persistence of the La Grulla population may also be related to the favorable hydrology of the site along the lower, out-flowing western end of the meadow, where water retention is highest. We recommend that cattle exclusion studies be conducted at La Grulla to help understand how grazing affects the long-term frog persistence at this site.

Most of the freshwater systems of the region are used for human recreation. We recorded recreation in arroyos Guadalupe, Maneadero, Santo Tomás, and San Vicente, particularly where there are hot springs. Arroyo San Carlos is heavily impacted by *balnearios* (swimming areas) constructed in the stream channel, destroying natural habitat for several kilometers. San Carlos is also listed as one of the most polluted aquifers in Baja California, along with Arroyo Tijuana (CONAGUA 2014). We found off-road vehicle activity in Cañón El Alamo, where stream channels are used as roads. This not only destroys breeding habitat, but may directly lead to frog mortality.

Another potential threat involves habitat siltation after heavy rains. Several ranchers report ponds were lost to siltation at sites 22, 27, 29, 32, and 37. After heavy rains in 2010, a large breeding pond that had been surveyed over five years at El Potrero was reduced to 80% of its original size (Bob Mailloux, pers. comm.). The remaining *R. draytonii* populations along the coastal and foothill areas in Baja California face other ongoing threats to survival, mostly from exotic species and water extraction. Further research is needed to understand the genetic structure and connectivity between populations, as well as their reproductive timing and seasonal habitat movements. Investigations on the effects of exotic species and cattle may further our understanding of potential long-term impacts on *R. draytonii*. Answers to these questions would be helpful for monitoring the remaining populations and for selecting a source population should future reintroductions in México and southern California be deemed necessary for the species' survival.

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Peralta-García et al.—Status of *Rana draytonii* in Baja California.



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Appendix Table 1. Historical museum records and published observations of *Rana draytonii* from Baja California, México arranged from north to south. Museum specimen catalog number or published literature is indicated for each locality. In parentheses is number of specimens and collection numbers: CAS = California Academy of Sciences; LACM = Los Angeles County Museum; MVZ = Museum of Vertebrate Zoology; SDNHM = San Diego Natural History Museum; UABC = Universidad Autónoma de Baja California; USNM = United States National Museum.

Tecate (1, SDNHM 10411). 20 mi south of Tecate (6, MVZ 31786–91). San Carlos Canyon, 7.3 miles east of Highway 1 (1, LACM 9803). San Tomás (1, USNM 37699). 12 miles east of San Vicente (1, SDNHM 61159). Arroyo San Rafael, near Colonet (1, Grismer 2002). Mike's Sky Ranch (3, LACM 137817, 1388519–20). Arroyo San Rafael, about 7 miles above Mike's Sky Ranch, Sierra San Pedro Mártir (1, MVZ 140736, Welsh 1988). San José, San Pedro Mártir (6, CAS 57482–3; MVZ 9663–4, 9837; SDNHM 42195; Welsh 1988). Rancho El Molino, 0.9 km downstream from road in Arroyo San Jose (1, UABC 1501). Rancho Las Cabras, Arroyo San Jose (2, CAS 57510; LACM 91123). La Jolla, San Pedro Mártir (Welsh 1988). Rancho El Potrero, (5, UABC 1504, 1623–4, 1627–8, Fidenci 2004). Rancho Viejo, Sierra San Pedro Mártir (Welsh 1988). Arroyo La Encantada, San Pedro Mártir (114, CAS 57045–57, 57073–171, 57610; SDNHM 36457; Welsh 1988). La Grulla, Sierra San Pedro Mártir (92, USNM 37700; CAS 12956–7, 57237–93; MVZ 9820–7, 9838–9, 51088–9; MVZ 140732–5; SDNHM 44283–6, 57441–50; UABC 1649–50). San Antonio head, San Pedro Mártir (Welsh 1988). Valladares (5, MVZ 9830–4). Rancho San Antonio, San Pedro Mártir (5, USNM 37701; MVZ 9835–6; UABC 878, 1223; Welsh 1988). Arroyo Santo Domingo, 3.7 miles east (by road) Colonia Guerrero (1, MVZ 171777; Fidenci 2004). San Ramón, mouth of Arroyo Santo Domingo (6, MVZ 9870–75).

Herpetological Conservation and Biology

APPENDIX TABLE 2. Sites surveyed for California Red-legged Frogs (*Rana draytonii*) in Baja California watersheds in 2013 and 2014. Sites are grouped by watershed and arranged from north to south. List includes sites where our survey confidently overlapped the location of historical *R. draytonii* (^H) records; alternative sites chosen because the historical record lacked precise locality data (proxy site; ^P); and additional sites we identified from photos as having potential habitat for *R. draytonii* (no symbol). Record year is the year of a historical observation of *R. draytonii* (parentheses indicate a single observation within the time span). Columns “2013” and “2014” indicated number of surveys per year (D = daytime survey; N = nighttime survey). Dist. indicates distance surveyed. Native anurans: Radr (*Rana draytonii*), Psca (*Pseudacris cadaverina*), Pshy (*P. hypochondriaca*), Anca (*Anaxyrus californicus*), Anbo (*A. boreas*). Threats: exotic species (E), livestock (L), recreation (R), water extraction (W), translocated trout (T).

Site ID and Locality name	Record year	2013	2014	Elev. (m)	Dist. (km)	Natives	Threats
<i>Tijuana Watershed</i>							
01- Rancho las Dos Cumbres, Arroyo Tecate ^P	1933	1D	-	620	1	Pshy, Anbo	E,L,W
02- Cañada Panda, 17 km SE Tecate		1D	-	580	1.5	Anca	E,R,L,W
03- Nejí		1D	-	915	0.2	Pshy, Spha	R,L,W
04- El Gato, Cañón Las Parras		2D	-	855	0.5	Pshy, Psca	E,R,L,W
05- Cañón El Alamo, Arroyo Las Palmas ^P	1939	1D,1N	1D	488	1.3	Psca, Pshy, Anca	R
06- Dam at Rancho El Compadre, Sierra Juárez		1D	-	1,115	0.2	Anca, Anbo	E,R,L,W
07- Rancho Talegas, Arroyo Las Calabazas		1D	-	1,180	1.0	Psca, Pshy,	E,R,L,W
08- Rancho Los Aguajitos		1D	-	930	1.0	Psca, Pshy, Anbo	E,R,L,W
09- Rancho San Faustino, Sierra Juárez		2D,1N	-	1,270	1.0	Psca, Pshy, Anca, Anbo	E,R,L,W
<i>El Morro Watershed</i>							
10- El Morro, Cañada El Morro		1D	-	5	2.0	-	E,R
<i>Guadalupe Watershed</i>							
11- Rancho San Juan de Dios, Arroyo La Calabaza		1N	-	1,260	0.4	Pshy	R,L,W
12- Cañón Agua Caliente, Arroyo Guadalupe		2D,1N	-	390	1.5	Psca, Pshy, Anca,	E,R,W
13- La Misión, Arroyo Guadalupe		2N	1N	1	0.5	Pshy	E,R,W
14- Arroyo Casa Verde, Sierra Juárez		2D,1N	2D,1N	1,370	1.7	Psca, Pshy, Anca,	R,L,W
15- Real del Castillo, Arroyo El Barbón		1D, 1N	1D	625	1.0	Psca, Pshy,	E,R,W
<i>Salsipuedes Watershed</i>							
16- Cañada Salsipuedes		1D, 1N	-	125	0.5	Psca, Pshy	W
<i>San Antonio Watershed</i>							
17- Cañada Miracielo		1D, 1N	1D	358	1	Psca, Pshy	E,R,L,W
<i>Manadero Watershed</i>							
18- 11.8 km E Hwy 1, San Carlos Canyon	1957	1D, 1N	1N	70	0.5	Psca, Pshy, Anbo	E,R,W
<i>El Zorrillo Watershed</i>							
19- Arroyo El Zorrillo, Ejido Uruapan		1D	-	187	0.8	Pshy	E,R,L,W
<i>Santo Tomás Watershed</i>							
20- Santo Tomás ^H	1905	-	-	160	-	-	W
21- Rancho Agua Caliente		3D,3N	-	495	2	Psca, Pshy	E,L
<i>San Vicente Watershed</i>							
22- 19.3 km E of San Vicente ^H	1978	2D,2N	2D,1N	218	3.5	Psca, Pshy, Anca	E,R,L,W
<i>San Rafael Watershed</i>							
23- Ejido Benito Juárez ^H	(1990's)	-	-	120	-	-	W
24- 23 km E of Colonet		1D,1N	2D,1N	220	1.0	Radr, Psca, Pshy, Anca	R,L,W
25- 32 km E of Colonet		-	3D,2N	340	3.5	Radr, Psca, Pshy, Anca	L,W

Peralta-García et al.—Status of *Rana draytonii* in Baja California.

26- 6.6 km West of Rancho Mike's Sky		1N	-	1,036	0.55	Pshy	T
27- Rancho Mike's Sky ^H	1970, (1973-9)	2D,2N	2D,1N	1,220	4.3	Psca, Pshy, Anca	R,W,T
28- Rancho Garet ^P	(1973-9)	1D,1N	-	1,350	0.8	Psca, Pshy	T
<i>San Telmo Watershed</i>							
29- Rancho Meling (San José), Arroyo San José ^H	1923-1952, (1973-9)	2D,2N	1D,1N	620	0.2	Radr, Psca, Pshy, Anca, Anbo	R,L,W
30- Rancho El Molino, Arroyo San José ^H	2006	3D,2N	-	555	1.5	Radr, Psca, Pshy, Anca	L
<i>Santo Domingo Watershed</i>							
31- Cañón La Jolla ^P	(1973-9)	-	2D,2N	1,560	2.1	Psca, Pshy	L
32- Rancho El Potrero ^H	2002-3, 2006	2D,2N	1N	890	1.5	Radr, Psca, Pshy, Anca, Anbo	R,L,W,T
33- Rancho Viejo ^H	(1973-9)	1D	1D	2,050	2.5	Pshy, Anbo	L,T
34- La Encantada ^H	1923-45, (1973-9)	2D,1N	-	2,130	4.0	Pshy, Anbo	L
35- La Grulla ^H	1905-2006	3D,2N	2D,2N	2,070	2.0	Radr, Pshy, Anbo	R,L
36- Arroyo La Víbora ^P	(1973-9)	-	2D,2N	1,880	1.0	Pscad, Anbo	T
37- Rancho Valladares ^H	1925	2D,2N	1D	720	3.0	Radr, Psca, Pshy, Anca,	L
38- 7.5 km S from Rancho Valladares	-	-	2D,2N	635	3.0	Radr, Psca, Pshy, Anca,	L
39- Rancho San Antonio ^H	1905-2004	2D,2N	2D,2N	560	1.0	Radr, Psca, Pshy, Anca,	L
40- Arroyo El Caballo	-	-	1D	500	0.5	Psca	--
41- San Ramón ^H	1925	-	-	6	-	-	W
42- 3.95 km E of Colonia Guerrero ^H	1977, 2002	-	-	60	-	-	W
43- 2 km S of Rancho La Canastilla	-	2D,1N	1D,1N	145	2.0	Radr, Pshy, Anca,	E,W
44- San Isidoro, Arroyo El Horno,	-	-	2D,2N	920	2.2	Psca, Pshy	L