

The invasive bullfrog *Lithobates catesbeianus* in oases of Baja California Sur, Mexico: potential effects in a fragile ecosystem

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Abstract The American bullfrog (*Lithobates catesbeianus*), considered as one of the world's worst invasive species because of its negative effects on native fauna, has been introduced into over 40 countries in four continents. The invasion status in Mexico is poorly known. The first known record for this species in the Peninsula of Baja California, northwestern Mexico is an individual collected 35 years ago. A great portion of the peninsula is an arid desert where the sources of freshwater are the spring-fed oasis and mountain arroyos that support rare and endemic species closely associated with wetland conditions. Humans, who have introduced alien species, inhabit many of those oases. The aim of this work was to document the presence of the exotic bullfrog in 40 oases and mountain arroyos in Baja California Sur state during 2006–2009. Bullfrogs were found in 25% of the oases sampled; 15% have confirmed records of breeding populations and five oases are new location records. Our results show a considerable increase (50%) in the number of oasis invaded by bullfrogs in only 8 years. The animal populations of rare or

endemic species associated with oases would be threatened by the arrival of bullfrogs. Actions for their control and eradication are urgently needed.

Keywords American bullfrog · Exotic · Invasive · Mexico · Oasis · Baja California Sur

Abbreviations

BCS The state of Baja California Sur
PBC The Peninsula of Baja California

Introduction

Native of eastern North America, the American bullfrog *Lithobates catesbeianus* (Shaw, 1802) is listed as one of the world's worst invasive alien species by the Invasive Species Specialist Group (ISSG) of the International Union for Conservation of Nature (IUCN) Species Survival Commission (<http://www.issg.org/>). It has been introduced into four continents and over 40 countries in the last century (Lever 2003; Laufer et al. 2008; Akmentins and Cardozo 2009). Exotic bullfrogs have negative effects of predation, competition, and the transmission of disease to the native amphibian fauna (see review in Kats and Ferrer 2003), also affecting populations of other small vertebrates (Bury and Whelan 1984; Schwalbe and Rosen 1988). Bullfrogs are of conservation concern for the native ecosystems where they are introduced.

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The status of the bullfrog invasion in Mexico is poorly known because of the lack of precision of locations and dates of introduction. Individuals have been collected in at least 17 Mexican states (Casas-Andreu et al. 2001; Avila-Villegas et al. 2007). The oldest known record for this species in the Peninsula of Baja California is from an individual collected at the Oasis San Ignacio in May 1975 (IBH-1092, National Collection of Amphibians and Reptiles, UNAM). Since then only two studies have reported the presence of the exotic bullfrog in oases of the PBC (Grismer and McGuire 1993; Grismer 2002). Although oases are unique relict ecosystems that support rare and endemic species (Grismer and McGuire 1993; Rodríguez-Estrella et al. 1999) and are considered as fragile ecosystems, little attention has been given to determine the distribution and status of exotic species that have been introduced into the oases. Here we document the current distribution of the exotic bullfrog by sampling 40 oases in the southern Baja California Peninsula in the BCS during 2006–2009.

Materials and methods

Invasion site

The oases studied here are dispersed all along BCS. The state has an area of 73,500 km² and comprises the southern half of the PBC south of the 28th parallel (Fig. 1). With exception of its southern portion (the Cape region), BCS forms the southwestern portion of the Sonoran Desert subprovince (Shreve and Wiggins 1964). High annual mean temperatures and low precipitation characterize the general climatic conditions in BCS. Mountains and plains dominate the landscape. About 60 typical oases, e.g. those showing a surface water body with hydrophilic plants (León-de la Luz and Domínguez-Cadena 2006), are found in BCS. Only four oases (San Ignacio, Mulegé, La Purísima, and San José del Cabo) have a water surface area greater than 1 km² and could be considered as small rivers. The surface area of the remaining oases is only between 10 and 600 m² (Rodríguez-Estrella et al. 2002).

Field surveys

We visited 40 oases across all BCS searching for bullfrogs. All oases were visited at least 2 times per

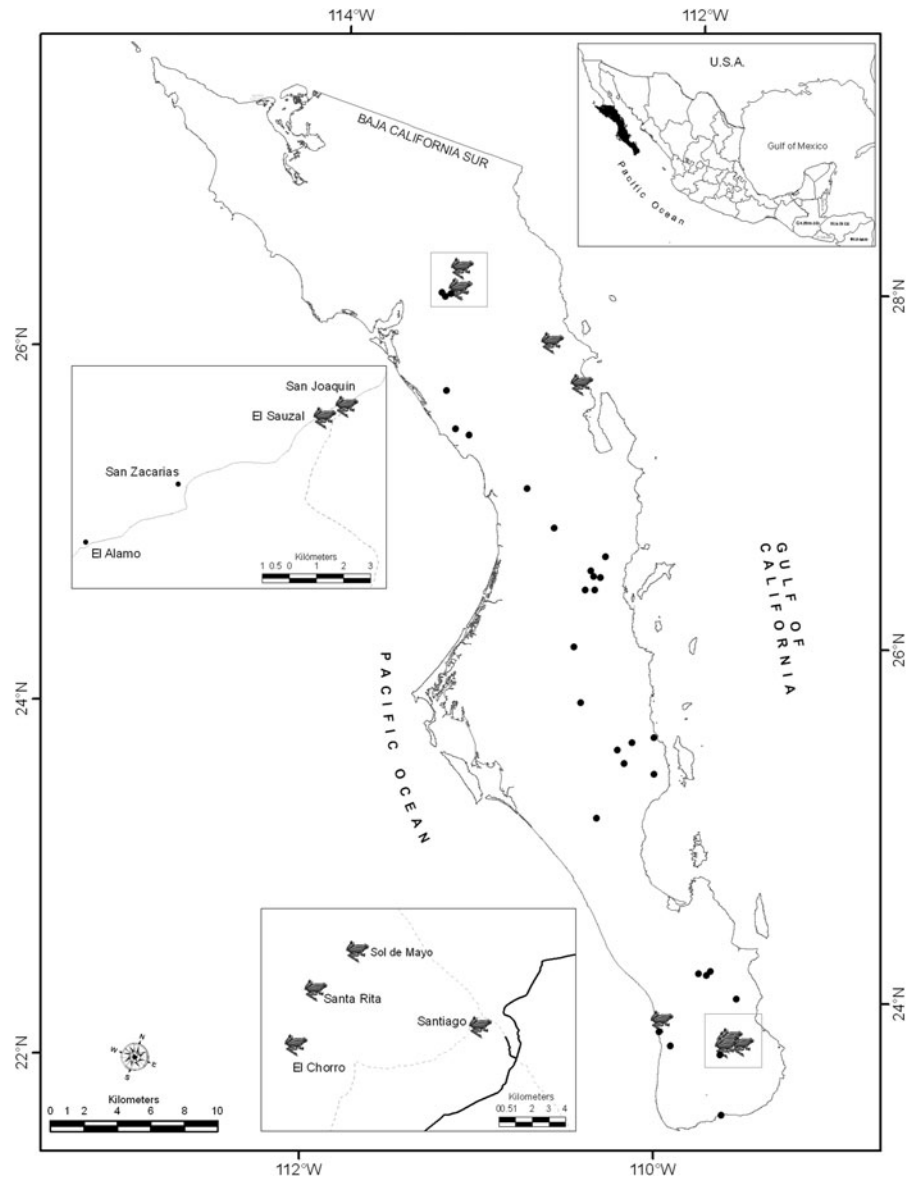
year during the two major seasons in the region; summer (May–October) and winter (November–April). During 2–4 days in every oasis, diurnal (from 0900 to 1200 hours) and nocturnal (from 2000 to 2400 hours) visual searches were made by teams of 2–4 persons walking slowly around the water body and edge vegetation searching carefully for any evidence of bullfrogs; sightings of adult frogs, juveniles, tadpoles, or egg masses, and listening for the typical call of this species. Although we interviewed local people, those anecdotal records with no confirmation of the record by us were not considered.

Results and discussion

We found exotic bullfrogs in 10 of the 40 oases visited (25%; Fig. 1). Five of these (San Joaquín, El Sauzal, Todos Santos, Santa Rita, and Sol de Mayo) are new locations for this invasive species in BCS. Evidence of breeding activity, i.e. vocalizing males, egg masses, tadpoles, and adults of well-established bullfrog populations, was found at six oases (San Ignacio, San Joaquín, El Sauzal, San José de Magdalena, Santiago, and El Chorro).

Our surveys confirm the persistence of bullfrog populations in the five oases where they were previously reported (Grismer and McGuire 1993; Grismer 2002), and also show that 25% of the oases sampled contain invasive bullfrogs, a large number of locations since the first known record 34 years ago. Our new records may be considered as part of a rapid invasion process of bullfrogs into the oases of BCS, or as a lack of previous studies in the new locations reported by us. We do not know the initial cause of the introduction of bullfrogs into BCS oases. However, our interviews with local ranchers indicate that people transport bullfrogs from one oasis to another simply because they want to have frogs in their ponds (F. Cota, personal communication). The oases are isolated and are surrounded by dry and hot environments that are a natural barrier for bullfrog oasis-to-oasis migration. Our distributional map (Fig. 1) suggests that the occurrence of bullfrogs in oases is not random and that their presence does not seem to follow a colonization pattern. Thus, we conclude that at present all new oasis records containing bullfrogs presented here resulted from human introduction.

Fig. 1 Location of the 40 oases (black dots plus bullfrog icons) sampled in 2006–2009 in the state of Baja California Sur, northwestern Mexico. Bullfrog icons are oases with the confirmed presence of bullfrogs



In their native range bullfrogs are mostly aquatic and prefer warmer, permanent water bodies with dense and emergent aquatic vegetation (Bury and Whelan 1984). All the oases where we found breeding populations have this structural pattern. Bullfrogs can persist in the oases if the habitat is without significant structural changes. An example of this is the bullfrog population at Oasis San Ignacio that was first reported 35 years ago and continues reproducing at the present time. If local people continue transporting bullfrogs between oases, we estimate that in the near future this species can successfully colonize

around ten bullfrog-free oases because those sites have a suitable habitat. It is likely that some “suitable” oases that are close to others and linked through arroyos could be naturally colonized after the rains that flood the arroyos and connect oases temporarily.

Adult bullfrogs are opportunistic predators that may prey on other frogs and a wide variety of invertebrates and vertebrates, including conspecifics (Bury and Whelan 1984). Introduced bullfrogs have been implicated in the decline and displacement of many amphibian and a few reptile species (Hammerson 1982; Schwalbe and Rosen 1988; Lannoo et al. 1994;

Kupferberg 1997; Kiesecker and Blaustein 1998). Grismer (2002) reported that bullfrogs in oases of the PBC ate Two-Striped Garter Snakes *Thamnophis hammondi*, lizards, mice, mosquito fish, and even hummingbirds and nestling birds. Because of the ecological requirements of many oasis-dependent species, we suspect that bullfrogs can potentially prey on endemic aquatic species as the Killifish *Fundulus lima* (Ruiz-Campos et al. 2006), the Baja California Treefrog *Pseudacris hypochondriaca curta* (Luja et al. 2007), several terrestrial species associated with mesic microhabitats, such as scorpions (Jiménez-Jiménez and Palacios-Cardiel 2009), spiders (Llinas-Gutiérrez and Jiménez 2004), lizards, and snakes (Grismer 2002). Therefore several endemic species that are oasis-dependent would be strongly affected by the predation pressure of the exotic bullfrog.

Additionally, it has been suggested that bullfrogs have possibly displaced the native Baja California Treefrog *P. h. curta* to less suitable habitats and that *P. h. curta* and the Two-Striped Garter Snake *T. hammondi* were scarce in oases with bullfrogs (Grismer and McGuire 1993; Grismer 2002). However, detailed studies are needed to establish clearly the ecological relationships among native and exotic species in oases.

Until now, amphibian populations of the BCS oases are apparently free of the chytrid fungus *Batrachochytrium dendrobatidis* (Frías-Alvarez et al. 2008) that can be potentially transmitted by bullfrogs. However, in that study few locations were sampled and more data are needed to ensure the health of native amphibian populations of BCS oases.

The animal populations of desert oases are geographically isolated by their naturally fragmented distribution, and for some species probably few individuals compose each population because of the small size of the oasis. It makes these species most susceptible to local extinction only by chance because both deterministic and stochastic events have strong effects on populations with few individuals (Pimm et al. 1998). The introduction of an exotic species as bullfrogs is an additional threat for these vulnerable populations.

Environmental education for the local people and eradication programs of the existing populations must be urgently implemented to prevent future introductions and additional pressures on the small and isolated populations of the oases of the Peninsula of Baja California.

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