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Notes

A New Insular Population of Arboreal Salamander (*Aneides lugubris*) in the San Francisco Bay

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***Abstract.*—The origin of island populations of herpetofauna is often unclear for some species. Successful colonization events are rare, and likely stochastic, but establishment does occur if current site conditions are suitable. We detected a breeding population of Arboreal Salamanders (*Aneides lugubris*) on a small rock island in the San Francisco Bay. The origin of this population is unknown, but it appears to be thriving amid anthropogenic structures and an altered landscape.**

Key Words.—colonization; island; population; rafting; reproducing

The range of some amphibian species can be enigmatic and may appear random, such as in the slender salamander (*Batrachoceps*) species complex of the southern Sierra Nevada (Sweet 2019). Species distributions may be patchy, with large gaps between disjunct and isolated populations of a single species complex, such as the Columbia Spotted Frog (*Rana luteiventris*; McGinnis and Stebbins 2018). Such population distributions may result from range contractions or colonization events over time (Tyler 1991; Marsh and Trenham 2001). Population isolation is known in the Arboreal Salamander (*Aneides lugubris*), which is found in three distinct, isolated, foothill populations on the California mainland (Sierra Nevada, North Coast Range, and South Coast Range), and are also one of the three amphibians (with the Garden Slender Salamander, *B. major*, and the Channel Islands Slender Salamander, *B. pacificus*) in California that occur on oceanic islands (Van Denburgh 1905; Anderson 1960; Banta and Morafka 1966; McGinnis and Stebbins 2018). It is found on Coronado Island, Baja California, Mexico (Grismer 2002), Catalina Island, Los Angeles County, California, and Año Nuevo Island, Santa Cruz County, California (McGinnis and Stebbins 2018), and North Farallon Island, San Francisco County, California (VanDenburgh and Slevin 1914; Lee et al. 2012). Arboreal Salamanders are also on islands in the San Francisco Bay including Angel Island, Marin County, Red Rock Island (at the convergence of San Francisco, Marin, and Contra Costa counties), and Brooks Island, Contra Costa County (Anderson 1960).

Storer (1925) and Schoenherr (2007) postulated that populations of Arboreal Salamanders on North Farallon Island originated from the mainland of the central coast, south of the Salinas River. Anderson (1960), studying the Arboreal Salamander on islands in the San Francisco Bay, believed that they either originated from surrounding mainland populations and colonized islands through rafting, or were remnant populations from approximately 10,000 years prior, when the bay was an inland valley and salamander populations were likely contiguous throughout the region. More recently, genetic work by Reilly et al. (2015) appeared to support the contention that populations of Arboreal Salamanders from North Farallon Island originated from mainland populations in Marin County, which they suggested may have been historically connected through a land bridge. Here we report on a new insular population of Arboreal Salamanders on a small rock island, East Brother Island, in the San Francisco Bay, Contra Costa County, California.

East Brother Island is a very small (0.3 ha) rocky island located 0.34 km west of Point San Pablo, Contra Costa County (Fig. 1; 39.962582°N, -121.433271°W). Historically, the island was a solid bedrock protrusion from the bay (similar to the adjacent West Brother Island)

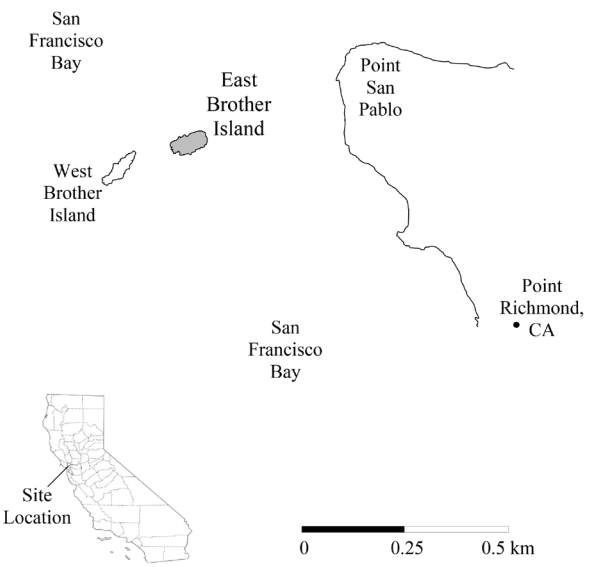

Figure 1. General location of East Brother Island, in northwest San Francisco Bay, relative to the Contra Costa County coast (Point San Pablo), California.

Figure 2. Historic conditions (circa 1893) of the East Brother Island, in northwest San Francisco Bay, California, while under the operation of the U.S. Coast Guard. Note the absence of vegetation. (Photograph courtesy of the National Archives and Records Administration).

that supported the roosting and nesting of numerous pelagic birds such as cormorants (*Phalacrocorax* spp.), pelicans (*Pelecanus* spp.), and gulls (*Larus* spp.; Perry 1984). In 1873 the island was leveled for construction of a lighthouse, fog-signal building, and associated structures, which were completed by 1874 (Perry 1984; Fig. 2). Based on a review of historic photos, East Brother Island remained largely barren during the first 100 y of the light station operation, although successive keepers generally kept personal gardens, and presumably planted ornamental plants, because mature Century Plants (*Agave americana*) appear in photographs from the early 1900s. By the 1940s, several Blue Gum (*Eucalyptus globulus*) and Monterey Cypress (*Cupressus macrocarpa*) trees had been planted, and ornamental succulents became much more widespread following the conversion of the property to a Bed and Breakfast establishment in 1980 (Perry 1984). Ground clutter, in the form of lumber and construction supplies, has been continually present throughout the history of the station due to the ongoing maintenance required to the wooden buildings on the island (Che Rodgers, pers. obs.). Today, East Brother supports a lighthouse, innkeeper residence, functioning Bed and Breakfast, and supporting infrastructure. Vegetation on the island consists of an array of ornamental plantings surrounding the lighthouse and associated buildings, a widespread cover of annual grasses and forbs, and patches of California Buckwheat (*Eriogonum fasciculatum*) around its perimeter (Fig. 3).

In Fall 2018 we conducted three separate informal surveys on the island totaling approximately 10 person hours, to determine if any herpetofauna might be present. Generally, we conducted surveys on clear, sunny days > 7 d after a previous rain. We checked every potential basking site and cover object for species that were known on nearby islands, but none were found. In the winter of

Figure 3. Structures and vegetation on East Brother Island, Contra Costa County, California, in 2019. (Photographed by Che B. Rodgers).

Figure 4. Adult and juvenile Arboreal Salamanders (*Aneides lugubris*) collected from under cover objects on East Brother Island, Contra Costa County, California, October 2019. (Photographed by Che B. Rodgers).

2018–2019, we conducted an additional, more focused, survey consisting of approximately eight person hours. We checked all potential cover objects (i.e., lumber piles, flowerpots, rocks, etc.), and we placed twenty-two 30 × 30 cm plywood cover boards around the perimeter of the island in areas with surface soils. For four weeks following their deployment, we checked coverboards opportunistically.

At three locations on the island, we found both adult and hatchling/juvenile Arboreal Salamanders under cover objects such as wood piles, terracotta pots, and flat rocks resting on soil (Fig. 4). All seven specimens we collected appeared to be healthy (i.e., no missing limbs, body condition appeared typical for the species, etc.) and were associated with what appeared to be appropriate microhabitat (Stebbins 1951; Rosenthal 1957). We found no other vertebrates under the cover boards.

The position of islands relative to prevailing currents may play a significant role in the beaching of raft materials and potential colonization. East Brother Island is in the direct line of out-going flow (at low tide) from San Pablo Bay (McGann et al. 2013) and appears to benefit from higher frequencies of intersection between raft materials and landform (Vences et al. 2003; Thiel and Haye 2006; Measey et al. 2006) than other islands in the bay. We think it likely that drifting debris that periodically washes up on the north side of the island has enabled these salamanders to colonize through rafting (See: Anderson 1960; Measey et al. 2006). If the dominant or exclusive manner in which transient colonization occurred historically (prior to the settlement of the island) was that Arboreal Salamanders did raft in on debris floating from the estuary into the bay, it is possible or probable that it took numerous events for colonization to occur. When the island consisted only of bare rock, population persistence was likely impossible for lack of microhabitat. Arboreal Salamanders benefited from later, anthropogenic alterations, such as construction of the lighthouse and associated structures, the creation of gardens, etc., that created new suitable and enduring habitat where none had previously existed. Alternatively (or concurrently), the intermittent importation of off-island soils, nursery stock, or lumber for human habitation may itself have carried individuals to the island over time (See: Storer 1925). In all likelihood, one or both factors contributed to the colonization of the island.

East Brother Island is one of only two human-occupied and/or developed islands in San Francisco Bay (along with Angel Island) known to support Arboreal Salamanders (Slevin 1928; Anderson 1960; Jeff Alvarez, pers. obs.). Some islands support California Slender Salamanders (*B. attenuates*), but not the Arboreal Salamanders (Stebbins 1951, Anderson 1960). Even islands that have had substantial soil infill and ornamental plantings (i.e., Treasure Island in San Francisco County) and/or thousands of tons of lumber transported onto them (i.e., Yerba Buena Island in San Francisco County), show no records of Arboreal Salamanders (i.e., museum specimens, iNaturalist accounts, or from our own surveys). The apparent absence of Arboreal Salamanders on some San Francisco Bay islands may result from inadequate surveys on those islands, or it may reflect surveys ill-timed to stochastic colonizing events. Conversely, the detection of Arboreal Salamanders on East Brother Island may have occurred because of high survey effort by three biologists searching a very small, open surface area. Irrespective of the origin, Arboreal Salamanders have colonized East Brother Island, and appear to be reproducing successfully. Maintaining the current lighthouse, residence for the lighthouse keeper, and all of the associated ornamental vegetation is likely critical to maintaining this newly discovered population of Arboreal Salamanders.

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Jeff A. Alvarez is a Herpetologist who has specialized in California reptiles and amphibians for more than 30 y. He has worked with California Red-legged Frogs **(***Rana draytonii*), California Tiger Salamanders (*Ambystoma californiense*), Western Pond Turtles (*Actinemys marmorata*), and Alameda Whipsnakes (*Masticophis lateralis euryxanthus*) for much of his career. His focus is on the conservation and natural history of herpetofauna, survey techniques development, and conducting peer-level special-status species workshops. (Photographed by Kelly Davidson).

Che B. Rogers is a mariner and Ferry Boat Captain, naturalist, musician, and woodworker, and was the lighthouse keeper on East Brother Island from 2017 to 2019. He holds a deep fascination with biology and the natural world, and when not on the water, can be found exploring for and photographing native reptiles and amphibians in their natural habitats. He currently lives in the Seattle, Washington, area. (Photographed by Ray Duran).

Jeffery T. Wilcox is an Ecologist who had spent much of his career managing large, working landscapes. He monitors the populations of native plants and animals to inform adaptive management decisions for landscape-scale tools such as prescribed fire and cattle grazing, with particular interest in how the widespread creation of small reservoirs in California has affected populations of native amphibians. (Photographed by Lou Silva).