

***Pupoidopsis hawaiiensis* Pilsbry & Cooke, 1921 (Gastropoda: Pupillidae):  
extirpated in Hawai‘i but a possible survivor  
in Kiribati and French Polynesia**

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*Pupoidopsis hawaiiensis* Pilsbry & Cooke, 1921, was described as an apparently extinct genus and species of land snail that had inhabited coastal lowlands on the islands of O‘ahu, Moloka‘i, and Maui in the Hawaiian Islands (Pilsbry & Cooke 1921 in Pilsbry 1920-1921). Subsequently, a living population of the species was found on the island of Kiritimati (formerly Christmas Island) in the Republic of Kiribati (Cooke in Gregory 1925, Anonymous 1926, Cooke & Neal 1928), and Pilsbry (1927-1935) added Kaua‘i and the Tuamotu Archipelago of French Polynesia to the known range of the species. Cooke (in Gregory 1935) and Christensen & Kirch (1986) reported its occurrence on Hao Atoll in the Tuamotu Archipelago, and, most recently, Gargominy & Meyer (2012) reported the discovery of a sub-fossil specimen on Toau Atoll, also in the Tuamotus.

*Pupoidopsis hawaiiensis* is noteworthy in that it is one of only four species of land snails that are native to the Hawaiian Islands but that also occur elsewhere (Cowie *et al.* 1995). The others are the Holarctic species *Vitrina pellucida* (Müller, 1774), formerly known as *Vitrina tenella* Gould, 1846 (Baker 1941, 1958, Forcart 1955, Roth & Sadeghian 2006), the North American *Striatura pugetensis* (Dall, 1895) (Baker 1941), and *Lamellidea gracilis* (Pease, 1871), which occurs also on Wake Island (Cooke & Kondo 1961).

This paper discusses the range of this species in the Hawaiian Islands and the chronology of its extirpation, provides the first records of its occurrence on Tabuaeran (Fanning) Island in Kiribati and on Niau and Fakarava Atolls in the Tuamotu Archipelago, and supplements previously available information regarding the possible survival of this rare species on Kiritimati (where living specimens were last collected in 1965) and perhaps elsewhere in Kiribati and the Tuamotus.

Collecting data for a geographically representative sample of Bishop Museum’s Hawaiian collections and for all non-Hawaiian material examined are presented in an Appendix. Catalog numbers are BPBM Malacology Collections numbers, except that specimens from the collection of the Academy of Natural Sciences of Philadelphia are identified by the acronym “ANSP”. Lots containing alcohol-preserved specimens (and that were thus certainly live-collected) are indicated by “(L)”. Collections were made by Donald Anderson (DA), S.C. Ball (SCB), C.M. Cooke, Jr. (CMC), T.T. Dranga (TTD), C.N Forbes (CNF), H.A. Pilsbry (HAP), J.F.G. Stokes (JFGS), d’Alte A. Welch (DAW), G.P. Wilder (GPW) and others, as indicated.

***Pupoidopsis hawaiiensis* in the Hawaiian Islands**

In the Hawaiian Islands, subfossil specimens of *Pupoidopsis hawaiiensis* have been found in a number of locations in the coastal lowlands of Kaua‘i, O‘ahu, Moloka‘i, and Maui. Bishop Museum holds 97 catalogued lots from these islands in addition to the uncatalogued material from archaeological and paleontological sites at Barbers Point (Honouliuli), O‘ahu, studied by Christensen & Kirch (1986) and Christensen (1995).

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As only a limited number of specific localities have been cited thus far in the literature, a geographically representative sampling of these 97+ records is presented below in the Appendix. Based on the known distribution of fossil occurrence of *P. hawaiiensis* in the Hawaiian Islands and the limited information available on its habitat preferences elsewhere, it appears that the species inhabited the “Coastal Dry Communities” formerly widespread in the Hawaiian lowlands but now much reduced in range (Wagner *et al.* 1985, Gagné & Cuddihy 1999). The “*Lepturus* Grassland” vegetation type (similar to the observed habitat of living *P. hawaiiensis* on Kiritimati) now survives only in the Northwestern Hawaiian Islands (Gagné & Cuddihy 1999).

Although there is no doubt that *P. hawaiiensis* no longer inhabits the Hawaiian Islands, the chronology of its extirpation has been the subject of some misunderstanding. Pilsbry & Cooke (in Pilsbry 1920-1921: 108) opined that *P. hawaiiensis* “belonged to the lowland fauna, which has been almost wholly destroyed by deforestation since the discovery of the islands by Europeans,” and Cooke & Neal (1928: 29) stated that “since the advent of the white man the abundant fossil material [in the Hawaiian Islands containing *P. hawaiiensis*] has come into existence.” More recently, however, it has become clear that the ecological changes that adversely impacted the native flora and fauna of Hawai‘i, including its native land snails, began soon after the initial human settlement of these islands and are not solely a phenomenon of the post-A.D. 1778 era (*e.g.*, Kirch 1982, 1985, Olson & James 1982, Athens *et al.* 1992, 2002, Athens & Ward 1993). The prehistoric introduction of the Polynesian rat, *Rattus exulans*, has had a particularly heavy impact on lowland and coastal vegetation (Athens 2009). Several studies have demonstrated the apparent extirpation of some of the native land snails formerly inhabiting Hawaiian coastal areas during the prehistoric period (Christensen & Kirch 1986, Christensen 1995, Dixon *et al.* 1997, Burney *et al.* 2001), and *R. exulans* was undoubtedly among the causative agents of these events. *P. hawaiiensis* survived into the period of prehistoric human settlement in the ‘Ewa Plain of southeastern O‘ahu (Christensen & Kirch 1986, Christensen 1995), but stratigraphic disturbance of sediments in the sinkhole sites studied thus far (Athens *et al.* 2002) makes it impossible to determine with certainty whether its extirpation there took place before or after the advent of European influence in A.D. 1778. The identity of the particular agent (or agents) of its demise there and elsewhere is similarly unknown, although presumably many of the influences leading to the destruction of the native lowland vegetation (Wagner *et al.* 1985, Athens *et al.* 2002, Athens 2009) and native land bird species (Steadman 1995, Boyer 2008) had similar effects on *P. hawaiiensis* and other native land snails. In light of the recent recognition of the important role of *R. exulans* in the prehistoric modification of the Hawaiian environment (Athens 2009, Drake & Hunt 2009), however, it is worth noting that the survival of *P. hawaiiensis* on Kiritimati notwithstanding the presence there of *R. exulans* since prehistoric times (Anderson *et al.* 2002) indicates that the introduction of this alien predator to the Hawaiian Islands was probably not, by itself, sufficient to cause the extirpation of *P. hawaiiensis*.

#### **New Island Records in Kiribati and the Tuamotu Archipelago**

Henry A. Pilsbry of the Academy of Natural Sciences of Philadelphia visited the Tuamotu Archipelago as a member of the 1929 Pinchot South Sea Expedition (Pilsbry 1930) and collected specimens of *Pupoidopsis hawaiiensis* on Toau, Niau, and Fakarava Atolls. Although this material was undoubtedly the basis for Pilsbry’s statement (1927-1935: 159) that *P. hawaiiensis* occurred in the Tuamotus, these records are reported here in full for the first time.

Members of Bishop Museum's 1934 Mangarevan Expedition also visited the Tuamotus, and their collections of *P. hawaiiensis* from Hao Atoll were the basis for the report by Christensen & Kirch (1986) that the species occurred there. They also visited Tabuaeran Island and collected *P. hawaiiensis* there, a record that has not previously been reported.

### Conservation Status

*Pupoidopsis hawaiiensis* is listed as "data deficient" in the International Union for the Conservation of Nature's *Red List of Threatened Species* (IUCN 2012); Gargominy & Meyer (2012: 130) suggest, however, that the species may be "globally in danger of extinction." Bishop Museum's malacological collections contain information that may assist in the assessment of the conservation status of possibly extant populations. Although *P. hawaiiensis* does not survive in the Hawaiian Islands, it has fared better elsewhere in its range. Members of the *Whippoorwill* Expedition found *P. hawaiiensis* to be abundant on Kiritimati in 1924. Although that island suffered considerable disturbance in World War II (Morrison & Woodroffe 2009), in 1965 G.A. Samuelson, a Bishop Museum entomologist, obtained living specimens of *P. hawaiiensis* on Kiritimati, and the species may well survive there. Specimens collected on Toau, Niau, and Fakarava Atolls by Pilsbry in 1929 appear to have been living or only recently dead, and living specimens were obtained on Tabuaeran and Hao Atoll in 1934 by Bishop Museum personnel (see List of Material). Any or all of these islands may still support living populations of this rare land snail species. The species does not appear to be generally distributed in the islands in and near Kiribati or in the Tuamotus, however. Members of the 1924 expedition searched for it unsuccessfully on Malden and Washington Islands (Teraina) in Kiribati, on Penrhyn (Tongareva) in the Cook Islands, and on Palmyra Atoll in the northern Line Islands (Cooke & Neal 1928), and it is not represented in collections made in 1934 on Flint Island, Kiribati, or in Bishop Museum's collections made in the Tuamotus during the period 1929 to 1934 from Makatea (Cooke 1934) and from Anaa, Fakahina, Hikieru, South Marutea, Takaroa, Tatakotu, and Tepoto Atolls. Accordingly, efforts to verify the survival of the species should concentrate on those islands identified above where live-collected material was obtained during the twentieth century or on nearby islands where no observations of the land snail fauna have yet been undertaken.

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#### APPENDIX: Material Examined

**HAWAIIAN ISLANDS, Kaua'i:** S side of Wailua River, CMC, 5 Mar 1910 (20928, 1 spm); Kōloa, Makahū 'ena Pt, JFGS, Nov 1911 (35806, 1 spm); Māhā 'ulepū, 1st dune from Kapunakea Pond, JFGS, 30 Jan 1916 (52096, 69 spms); Kealia, sand bank between mill & road, CMC, 18 Oct 1922 (77853, 1 spm); S Wailua, flat, along road & in sand cuttings, CMC, 10 Sep 1930 (100121, 28 spms); Waipouli, CMC, 10 & 16 Sep 1930 (100171, 2 spms); Māhā'ulepū, 'Aweoweonui, CMC, 23 Oct 1930 (100549, 2 spms); Hanamā'ulu flat, roadside cutting for fill of detour, 100–150 ft N of Hole #1 of golf course, just N of golf course fence, CMC, 8 Apr 1933 (116663, 1 spm); Hanamā'ulu, 20 yds E of new road & W of ditch, CMC & HAP, 20 Jul 1933 (119011, 16 spms); Wailua, 3/10–4/10 mi S of Wailua River, above 300 ft from beach, G.F. Arnemann, 1 Feb 1947 (210172, 1 spm). **O'ahu:** Kaipapa'u, CMC *et al.*, Sep–Oct 1912 (33561, 1 spm); 'Ewa, coral plain below Sisal, in coral pits, CMC & CNF, 16 Feb 1912 (35631, 8 spms); Kailua, Kawailoa, base of coral ridge about 1 mi from shore, CMC *et al.*, 23 Jun 1912 (35731, 61 spms); Kailua, Mōkapu Point, CFN & JFGS, 20 Apr 1912 (35784, 1 spm); Wai'anae Mts, Lualualei, face and top of ... coral ridge S of Mt Pu'uohulu, CMC & CNF, 17 Apr 1914 (40866, 3 spms); Kāne'ohe, Heleloa sand dunes, JFGS, 24 May 1915 (40935, 5 spms); Mālaekahana, sand dunes mauka of govt. road, CMC *et al.*, 6 Apr 1917 (44794, 21 spms); Kahuku, coral bluff 1–1/2 mi W of mill, CMC & HAP, 18 Jan 1913 (45238, 6 spms); Kāne'ohe Bay, Kapapa Islet, JFGS, 12 Sep 1917 (52517, 1 spm); just W of Lā'ie Stream, CMC & HAP, 18 Jan 1913 (52970, 1 spm); Waimānalo sand dunes mauka of Kalaniana'ole Highway, DAW, 22 Mar 1933 (172811, 112 spms); Waialele, Lā'ie Hill, quarry 2/10 mi from Kamehameha Highway and N of Waialele Gulch, on top slope of hill, S side, DAW & G.W. Russ, 31 May 1933 (173075, 82 spms); Pūpūkea, along road to beach and in bank near Waimea Station, DA & M. Real, 5 Dec 1935 (175640, 1 spm); Mōkapu Point, BPBM Anthropology Dep, 8 Apr 1938 (180834, 14 spms). **Moloka'i:**

“Kalaeokalio” [probable error for Kalaeoka‘ilio] Paddock, coral hill just W of where pipeline crosses shifting sands, CMC *et al.*, 19 Mar 1914 (37484, 106 spms); Maunaloa slope, above Mo‘omomi, CMC, 16 Feb 1915 (40111, 20 spms); Maunaloa slope, above Mo‘omomi, Kalainawawae, CMC, 16 Feb 1915 (40137, 2 spms); Kalainawawae, CMC, 15 Dec 1916 (42551, 1 spm); Kaiehu, W of Mo‘omomi, inland 350 yds  $\pm$ , alt 20–60'  $\pm$ , N of old windmill, DA *et al.*, 8 Aug 1933 (184479, 95 spms); Kaiehu, W of Mo‘omomi, inland 200 yds  $\pm$ , alt 30'  $\pm$ , DA *et al.*, 8 Aug 1933 (184529, 300 spms); Kalani, W of Mo‘omomi, inland 150 yds, alt 20–30'  $\pm$ , DA *et al.*, 8 Aug 1933 (184556, 2 spms). **Maui:** Wailuku, sand hills from back of Wailuku Electric Light station, opp. Wailuku baseball park, CMC, 21 May 1915 (39994, 1 spm); Waihe‘e, sand dunes W of Penhallow’s beach house, CMC *et al.* 22 May 1915 (40005, 16 spms); Wailuku, sand hills below town, from cut, D.T. Fleming, 20 Dec 1920 (59787, 250 spms); Waihe‘e, back of heiau, JFGS, Nov 1916 (77719, 9 spms); Waiehu golf course, in sand dunes just above 1st hole, D.T. Fleming, 1 Dec 1932 (115921; 10 spms); near ‘Alaeloa, in sandy soil, CMC & H. Stearns, 6 Feb 1937 (167900, 2 spms).

**KIRIBATI, Tabuaeran (Fanning) Island:** NE. islet, flat, inland 30 yds, “under stones, logs, on tree trunks, bunchgrass & dead leaves,” DA, H. St. John, & R. Fosberg, 23 Apr 1934 (136184, 1 spm (L)). **Kiritimati (Christmas) Island:** Pologne, “under coconut trees in bunch grass,” TTD, 6 Aug 1924 (77799–77800, 4 spms); Motu Manu, “on bunch grass,” TTD, 3 Aug 1924 (77802–77813, 1535 spms (L)); R2, Rapa, “bunch grass,” D. Rogers, 10 Dec 1924 (79436–79440, 281 spms (L)); S. of ‘Abalone,’ “under bunch grass near beach,” D. Rogers, 10 Dec 1924 (79442–79447, 83 spms (L)); W of ‘Abalone’, “under bunchgrass,” SCB, 10 Dec 1924 (79450, 12 spms); Pologne, “under bunchgrass,” SCB, 10 Dec 1924 (79452–79453, 113 spms (L)); 1/2 mi N of London settlement, “on 1 tuft of bunchgrass,” SCB & GPW, 13 Dec 1924 (79457–79477, 195 spms (L)); 1 mi N of London, “low flats, on bunchgrass,” SCB, 15 Dec 1924 (79481–79485, 40 spms (L)); near Palone, GPW, 20 Dec 1924 (79486, 1 spm); “Moku Manu (probably; original label discolored),” SCB, 15? Dec 1924 (79487–79493, 588 spms (L)); “original label discolored,” SCB, Dec 1924 (79499–79503, 308 spms (L)); near airport, G.A. Samuelson, 14 Mar 1965 (276959–276960, 3 spms (L)).

**FRENCH POLYNESIA, Tuamotu Archipelago: Toau Atoll:** HAP, Pinchot Expedition, 3 Oct 1929 (10016 *ex* ANSP 150974, 1 spm; ANSP 150973, 14 spms; 118511 *ex* ANSP 150973, 4 spms). **Niau Atoll:** “purchased from natives,” HAP, Pinchot Expedition, 3 Oct 1929 (ANSP 156351, 64 spms, 118518 *ex* ANSP 156351, 18 spms). **Fakarava Atoll:** HAP, Pinchot Expedition, 3 Oct 1929 (ANSP 150834, 6 spms, 118526 *ex* ANSP 150834, 1 spm). **Hao Atoll:** 3/4 mi S.E. of village, dry, flat, inland 200 yds, “on tree trunks & twigs,” DA & CMC, 18 May 1934 (136562–136563, 6 spms (L)); Te Ketika, 50 yds from lagoon, “under or near *Tournefortia* tree,” DA & CMC, 19 May 1934 (36597–136599, 20 spms (L)).