

Land Snails of Dãno' (Cocos Island), Mariana Islands¹

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Abstract: We performed the first survey of terrestrial gastropods on Dãno' (Cocos Island). Dãno' is a 0.33 km² uninhabited atoll island located 2.5 km southwest of Guam, the largest island in the Mariana archipelago, western Micronesia. In 4 days of examining vegetation, soil, and leaf litter, we found 14 species of mollusks arrayed in 12 genera and 11 taxonomic families. The fauna is a subset of that found on Guam. Five species are native to the Mariana Islands, two of which are endemic to the archipelago, and the remaining seven are likely introduced there, perhaps prehistorically. Ground-inhabiting species found only as abundant worn shells in soil suggest relatively recent turnover of these forms, perhaps from seawater inundation of the low-lying island during typhoons. There was no evidence of Mariana endemic snails in the family Partulidae, recently afforded legal protection under the U.S. Endangered Species Act. However, neither did we encounter the invasive flatworm *Platydemus manokwari* De Beauchamp, currently decimating partulids elsewhere in the Marianas. Hence, we suggest that if further surveys confirm the predator's absence, Dãno' might serve as a novel sanctuary for transplanted populations of Guam's most endangered snails.

Keywords: atoll, Micronesia, dispersal, species turnover, *Omphalotropis*, *Truncatella*, *Palaina*

DãNO' (COCOS ISLAND) is a small atoll island in the Mariana archipelago, western Micronesia, and is geologically (Tracey et al. 1964:88), as well as politically, part of the much larger adjacent island of Guam, an unincorporated U.S. Territory. Because of Dãno's small size, limited habitat diversity, and proximity to Guam, the island's flora and fauna have rarely

been investigated scientifically, perhaps because they are expected to be composed of an abbreviated set of species inhabiting its larger neighbor.

Nevertheless, Dãno' possesses several interesting biological features rare or absent elsewhere in the archipelago. Its vegetation was documented by Neubauer and Neubauer (1981), and a representative collection is curated at the Guam Herbarium (Kerr et al. 2015). Eldredge (2003) recorded the stranding of a rare leatherback sea turtle, *Dermochelys coriacea* (Vandelli). Lizards were surveyed by McCoid (1996) before and after two severe typhoons. Wiles et al. (1993) provided an account of new bird records and nesting species. Recent interest in the island as a refuge for Guam's native vertebrate fauna (Wiles et al. 2003) has been motivated by its lack of the invasive snake *Boiga irregularis* (Merrem) that has eradicated most native lizards, birds, and bats on Guam (Savidge 1987). As a result, Dãno' now hosts one of two remaining wild populations of the endemic, flightless Guam rail, *Hypotaenidia* (= *Gallirallus*) *owstoni*

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(W. Rothschild), as well as the Mariana endemic scincid lizard *Emoia slevini* Brown & Falanruw, now extinct over most of its former range (Allison et al. 2013).

As best as we can determine, there are no accounts of the land snails of Dãno'. The earliest naturalist to visit the Mariana Islands, Antonio de Pineda y Ramírez with the Spanish Malaspina Expedition, mentioned Dãno' (as "*Isla de Cocos*"), but he did not visit the island (Pineda 1792, unpubl., in Mallada and Driver 1990:27). Later, a colonial governor of the Marianas, Luis de Ibáñez y García (1887, unpubl., in Driver 1992:88), came ashore briefly, describing "*Daneono*" as an uninhabited sand and limestone island with few trees. Other major nineteenth- and early twentieth-century accounts of Mariana biodiversity, including snails, made no mention of Dãno' (Quoy and Gaimard 1832, Quadras and Möllendorff 1894, Safford 1905, Prowazek 1913, Crampton 1925). The earliest observations on the land snails of the island were ap-

parently in 1888 by a naturalist collecting in the Marianas for the Paris Museum, Antoine-Alfred Marche (1891:24) (Cheng 1982:25), who noted that during his short visit to "*Danao*" he found "some interesting terrestrial molluscs . . .".

In this article, we provide the first account of land snails from the island of Dãno'. For 4 days beginning in late 2015, we surveyed all major habitat types across the island with emphasis on searching for species recently assigned protection under the U.S. Endangered Species Act (U.S. Fish and Wildlife Service 2015).

Study Site

Dãno' (0.33 km²) (13.239° N, 144.653° E) is a small, sandy island 2.5 km southwest of Guam, Mariana Islands, Micronesia (Figure 1). The island is situated atop an otherwise submerged atoll forming a barrier reef with a well-developed lagoon flanking Guam. The

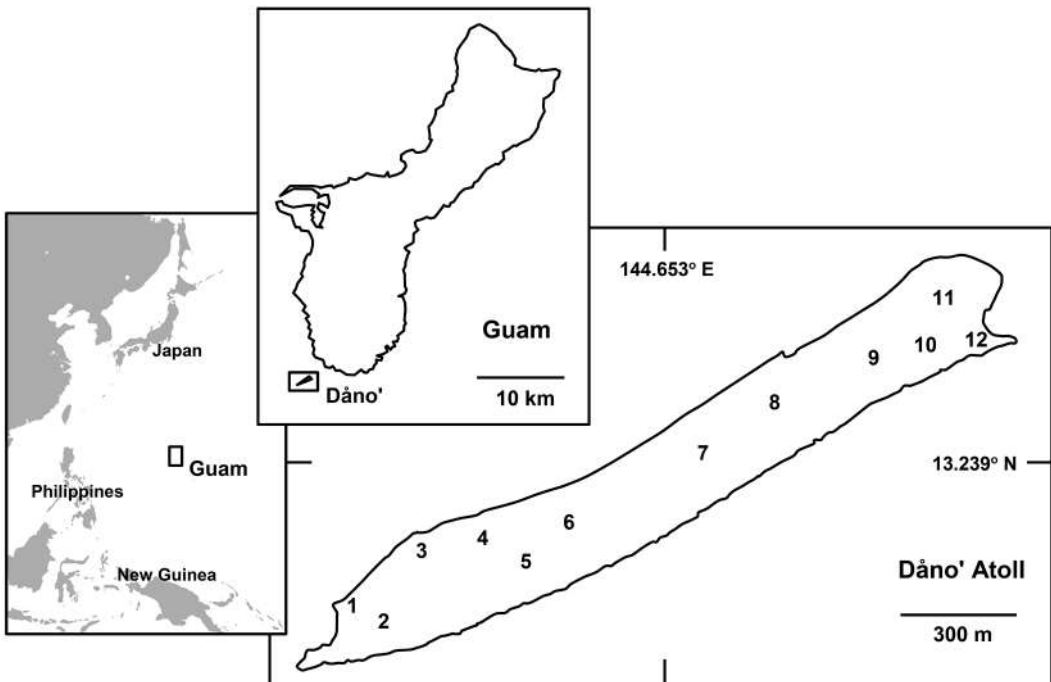


FIGURE 1. Map of Dãno' with approximate locations of numbered collection sites (map of Guam after www.freemap.jp).

island's exposure and maximum elevation of about 2 m render it vulnerable to flooding by typhoon-generated waves (Wells 1991). There are no permanent human inhabitants, but several hundred tourists per annum visit a small day resort operating there. Previous land use by humans has also considerably altered the environment (Neubauer and Neubauer 1981, McCoid 1996). Nevertheless, Dãno' is now almost entirely forested: the northern half with an extensive stand of *Casuarina equisetifolia* L., and the southern half largely of native back-strand trees, principally *Hernandia sonora* L., *Cordia subcordata* Lam., *Guettarda speciosa* L., and *Cocos nucifera* L. Seaward of the forests lies a circumisland skirt of cosmopolitan strand vegetation, primarily *Scaevola taccada* (Gaertn.) Roxb. and *Heliotropium foertherianum* Diane & Hilger (= *Tournefortia argentea* L. fil.), with the seawardmost karstic exposures along the windward east coast hosting stands of *Pemphis acidula* J. R. Forst. & G. Forst. Centrally, the island also supports two diminutive (ca. 0.1 ha total) wetlands maintained by a subterranean lens of freshwater recharged by precipitation (Ayers and Vacher 1986), the northern one a pond rimmed with Cyperaceae, the southern one often without standing water and shaded by giant taro, *Alocasia macrorrhizos* (L.) G. Don.

MATERIALS AND METHODS

During the wet season, snails were collected by two persons during the day across Dãno' (13 November and 30 December 2015, 24 November 2016, 2 March 2017). Collections were made by examining the undersides of leaves, sifting through leaf litter, and digging through the top 5–10 cm of soil at 12 haphazardly selected, roughly equidistant sites among five distinctive habitat types found on the island: *Casuarina* forest (sites 10, 11 in Figure 1), strand (1, 12), native back-strand forest (2–4, 6), wetland (5, 9), and ornamental vegetation near buildings (7, 8). Snail identifications were based primarily on original descriptions and revisionary monographs of Pacific-island taxa as referenced in Kerr and Bauman (2013) or in consult with specialists

(see Acknowledgments). Species were categorized as either having been collected (1) live, and if not, then (2) as fresh shells, meaning the shell was still pigmented or translucent, entire, and polished internally, but if not, then only (3) as bleached, eroded, and sometimes partial shells. Representative specimens of each species collected were deposited in the Bernice Pauahi Bishop Museum Malacology Collection (accession number 2017.089, catalogue numbers BPBM 283822–283834).

RESULTS

Table 1 lists the species collected on Dãno'. The table also indicates the species' biogeographic status: native, indicating that the species naturally occurs in the Marianas but is also found elsewhere; endemic, if it is only reported from the Marianas; and introduced, if it has likely been brought by humans to the archipelago, including through prehistoric transport. Approximate collection sites are shown in Figure 1. No terrestrial mollusks were found at site 10.

Several identifications warrant comment. *Pacificella variabilis* (Figure 2A) is distinguished from the similar Mariana achatinellid genus *Lamellidea* Pilsbry by fewer and more convex whorls, more obtuse apex, and less-impressed sutures (Cooke and Kondo 1960). The larger *Omphalotropis* (Figure 2B) most closely matched descriptions of *O. elongatula*, including having a shell of mostly solid colors of either tan or orange as seen in our exemplars. The second *Omphalotropis* was smaller with stepped whorls. Among the three species of Mariana *Omphalotropis* displaying the latter character (Kerr and Bauman 2013), only *O. granum* (Figure 2C) has a combination of coastal habit, smooth shell, and wide separation of the basal carina and columella as in our specimens. Our examples, however, seemed somewhat smaller, to a maximum ca. 3 mm in height, sans trace of peripheral angulation on the body whorl. *Liardetia sculpta* (Figure 2G) is the only Mariana species from this genus lacking spiral striae on the body whorl and hence the beading pattern that results from the crisscrossing of the threadlike axial ribbing (Baker 1938). Finally, *Truncatella mari-*

TABLE 1

Terrestrial Snails of Dãno', Their Voucher Numbers, Biogeographic Status within the Mariana Islands, Shell Condition, and Collection Sites

Taxa	BPBM ^a	Status	Condition	Sites ^b
Achatinellidae				
<i>Pacificella variabilis</i> Odhner, 1922	283832	Introduced	Fresh shell	6
Achatinidae				
<i>Achatina fulica</i> (Bowdich, 1822)	NC	Introduced	Live	7,8
Assimineidae				
<i>Ompbalotropis elongatula</i> Quadras & Möllendorff, 1894	283822	Native	Live	3,4,6
<i>O. granum</i> (Pfeiffer, 1854)	283823	Native	Worn shell	2-4
Diplommatinidae				
<i>Palaina taeniolata</i> (Quadras & Möllendorff, 1894)	283831	Endemic	Live	6
Ellobiidae				
<i>Melampus luteus</i> (Quoy & Gaimard, 1832)	283826	Native	Fresh shell	1
<i>Pythia scarabaeus</i> (Linnaeus, 1758)	283825	Native	Worn shell	3
Euconulidae				
<i>Liardetia sculpta</i> (Möllendorff, 1893)	283828	Introduced	Live	4,6
Hydrocenidae				
<i>Georissa laevigata</i> (Quadras & Möllendorff, 1894)	283830	Endemic	Live	2,6
Subulinidae				
<i>Allopeas gracile</i> (Hutton, 1834)	283833	Introduced	Live	2-6,8,11
<i>A. clavulinum</i> (Potiez & Michaud, 1838)	283834	Introduced	Live	3,4,6,7
Truncatellidae				
<i>Truncatella mariannarum</i> (Quadras & Möllendorff, 1894)	283827	Native	Live	1,3,12
Veronicellidae				
<i>Veronicella cubensis</i> (Pfeiffer, 1840)	NC	Introduced	Live	3
Vertiginidae				
<i>Gastrocopta pediculus</i> (Shuttleworth, 1852)	283829	Introduced	Live	2,3,6

^a Bernice Pauahi Bishop Museum Malacology Collection number; NC, not collected.

^b Site numbers from Figure 1; no snails were found at site 10.

annarum (Figure 2K, L) is about the same size and shape as another Guam congener, the more geographically widespread *T. guerinii* A. & J. Villa. They may even prove to be conspecific but are thought to differ in that the former has thinner, less exert costae (Harry 1966), as in all of our specimens.

One species that we did not see, *Achatina fulica*, is nevertheless included here because it is an abundant and unmistakable invasive on Guam (Mead 1961), and resort gardeners insisted that specimens are commonly seen low on building exteriors following sufficient rain. Further, another invasive species, the slug *Veronicella cubensis*, was photographed (Figure 2N) but not examined anatomically, and thus its identification remains provisional, being based on its gross appearance, widespread occurrence in neighboring Guam, and the

absence of other veronicellids from that island (Robinson and Hollingsworth 2006).

DISCUSSION

There are now 14 species of terrestrial mollusks reported from Dãno', including 10 pulmonates and four caenogastropods. No land snails or slugs have previously been listed from this island by others, hence all qualify as new distributional records. In addition, one species, the cosmopolitan invasive *Allopeas clavulinum* (Figure 2I), is a new distributional record for the Mariana Islands and so probably also occurs on at least Guam. The species recorded were from 12 genera in 11 taxonomic families. Five species (36%) are native to the Mariana Islands, two (14%) of which appear restricted to the archipelago, and the

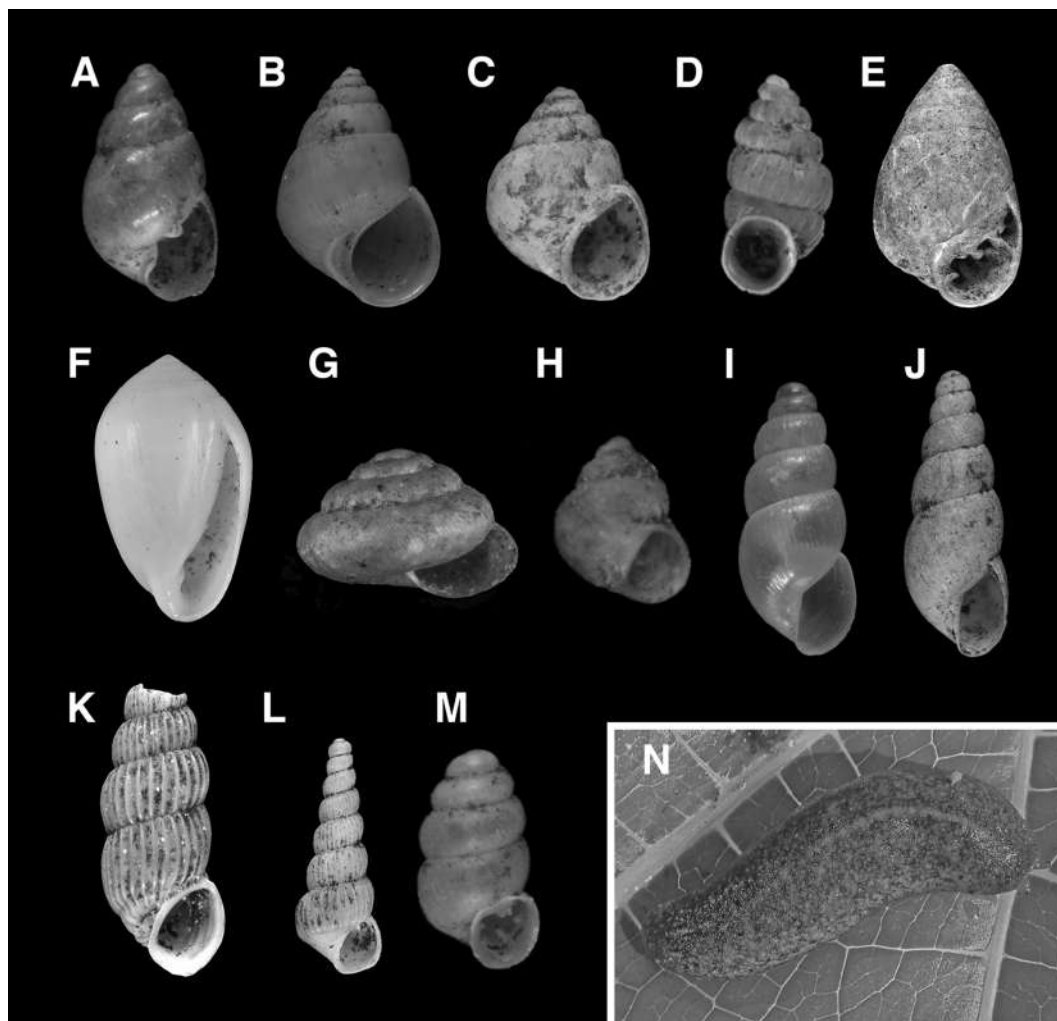


FIGURE 2. Terrestrial malacofauna of Dãno' (not to scale; measurements indicate shell heights). (A) *Pacificella variabilis* Odhner, 2.8 mm; (B) *Omphalotropis elongatula* Quadras & Möllendorff, 3.9 mm; (C) *O. granum* (Pfeiffer), 3.0 mm; (D) *Palaina taeniolata* (Quadras & Möllendorff), 2.5 mm; (E) *Pythia scarabaeus* (L.), 16.2 mm; (F) *Melampus luteus* (Quoy & Gaimard), 16.0 mm; (G) *Liardetia sculpta* (Möllendorff), 2.1 mm; (H) *Georissa laevigata* (Quadras & Möllendorff), 1.7 mm; (I) *Allopeas clavulinum* (Potiez & Michaud), 5.0 mm; (J) *A. gracile* (Hutton), 6.3 mm; (K) *Truncatella mariannarum* (Quadras & Möllendorff) adult, 6.4 mm; (L) *T. mariannarum* pre-decollate immature, 5.1 mm; (M) *Gastrocopta pediculus* (Shuttleworth), 2.4 mm; (N) ex situ live *Veronicella cubensis* (Pfeiffer), 56 mm mantle length. (Color in online version only). (Photos: A–M, G. C. Fiedler; N, A. M. Kerr.)

remaining seven (50%) are certain or probable introduced forms (Table 1). Ten species (72%) were seen alive and another two (14%) as fresh shells, whereas the remaining two species were each seen only as multiple exem-

plars of worn, eroded shells, suggesting that they are now rare or no longer occur on Dãno' (see following discussion).

The land-snail fauna of Dãno' is a subset of mostly abundant coastal species found on

Guam, which has at least 100 species of snails, including undescribed forms (Kerr and Bauman 2013). The diversity on Dãno' is also similar in composition and richness to that of other atoll snail faunas, suggesting that these species are better at dispersal or recruitment into these environments (e.g., Harry 1966, Christensen and Weisler 2013). Some species probably arrived on Dãno' via human agency (e.g., in soil associated with transported plants). However, Kondo (1955:198), while surveying in the Northern Mariana Islands, discovered two genera of native snails in the plumage of a single sooty tern: a *Succinea* sp. (Succineidae) and an *Elasmias* sp. (Achatinellidae). Hence, other snails, especially small native species, may have arrived on birds and bats, which still roost or nest on Dãno'.

There is the possibility of high turnover of snail species on Dãno'. Two of the 14 species, *Pythia scarabaeus* and *Omphalotropis granum*, inhabit leaf litter on atoll islets elsewhere in Micronesia (Harry 1966) but were found on Dãno' only as abundant, but heavily worn shells buried in soil. If these and perhaps other ground-dwelling species are no longer extant on Dãno', their elimination may have occurred through overwash of the low island from waves during typhoons that frequent the region (Wells 1991). The island has been submerged at least once by typhoon-generated waves since the early 1990s (McCoid 1996). On the other hand, and encouragingly, the molluscivorous flatworm *Platydemus manokwari* De Beauchamp, long devastating Guam snails (Hopper and Smith 1992), does not appear to be present on Dãno', despite probable transport among other islands in the archipelago, apparently in the soil of introduced plants (Smith 2013).

The distribution and abundance of snails within Dãno' seemed mediated by habitat type (Table 1). We investigated five main vegetation types on the island: *Casuarina* forest, beach strand, native back-strand forest, wetland, and ornamental vegetation near buildings. Fewer individuals and species of snails occurred in the open and relatively xeric *Casuarina* forest and near human habitation than in native back-strand forest. The latter habitat sheltered the likely prehistorically in-

roduced *Pacificella variabilis* (Figure 2A) and Mariana forest native *Georissa laevigata* (Figure 2H). Two other natives are specialists of the wave-splashed *Pemphis*-dominated zone, *Melampus luteus* (Figure 2F) and *Truncatella mariannarum* (Figure 2K, L), both originally described from Guam (Quoy and Gaimard 1832, Quadras and Möllendorff 1894). As well, the tropical cosmopolitan subulinids *Allopeas clavulinum* (Figure 2I) and *A. gracile* (Figure 2J) were found more widely (Table 1). One species appeared to be more abundant, at least as shells, on Dãno' than on Guam: *Gastrocopta pediculus* (Figure 2M), widely introduced in the tropical Pacific islands (Cowie 2000).

Expected to also occur on Dãno', but not seen, were several species abundant in similar vegetation on Guam and atolls Micronesia-wide (e.g., Harry 1966, Christensen and Weisler 2013). These include the other common Mariana subulinids *Subulina octona* (Bruguère) and *Paropeas achatinaceum* (Pfeiffer), found in back-strand and near ornamental plantings throughout the archipelago. As well, *Elasmias quadrasii* Quadras & Möllendorff (Achatinellidae) is a tiny, common, arboreal, and probable Micronesian native not seen on Dãno', but occurs on other Micronesian atolls (Harry 1966). Species such as these may turn up with future surveying.

Other species, however, appear to be genuinely absent, perhaps because of a lack of appropriate habitat or dispersal limitation. For example, the recent invasives *Drymaeus multilineatus* (Say) (Bulimulidae) and *Ganesella succincta* (Adams) (Camaenidae) are in recent years among the most conspicuous and abundant snails of primary and secondary habitats throughout Guam (Kerr and Bauman 2013) but were not encountered. As well, no freshwater species were seen in the small wetlands, not even cosmopolitan forms dominating ephemeral pools in Guam, such as *Physa* cf. *acuta* Draparnaud (Physidae) or *Melanoides tuberculata* (O. F. Müller) (Thiaridae).

Finally, there was also no evidence in Dãno', despite apparently suitable habitat, of the endemic Mariana species in Partulidae, of late receiving increased scientific and conservation attention (Smith 2013, Hadfield 2015,

Gerlach 2016, Kerr and Fiedler 2016). The four remaining species from the Marianas have recently been accorded federal legal protection under the U.S. Endangered Species Act (U.S. Fish and Wildlife Service 2015). The three species still inhabiting Guam (Hopper and Smith 1992) are largely restricted to coastal native forest like that found in southern Dãno' but are in decline, primarily from the invasive molluscivorous flatworm *Platydemus* (Hopper and Smith 1992) discussed earlier. Partulids may never have dispersed to Dãno' given the absence of even worn shells in soil, despite the ubiquity of such shells across the nearby island of Guam (Kerr and Bauman 2013) and other Mariana islands (Bauman 1996, Smith 2013). Regardless, if a comprehensive survey proves that Dãno' is free of the predatory flatworm, then with safeguards the island may serve as a much-needed sanctuary for threatened native gastropods, just as it now affords refuge from exotic predators to some of Guam's most endangered vertebrate species (McCoid 1996, Wiles et al. 2003).

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