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# A New Subspecies of *Leporicypraea mappa* (Linnaeus, 1758) from the Marquesas, French Polynesia (Mollusca: Gastropoda: Cypraeidae)

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**ABSTRACT** A new subspecies of *Leporicypraea mappa* (Linnaeus, 1758) from the Marquesas Islands, French Polynesia is described as *Leporicypraea mappa curvati* n. ssp. It is separated from two other principal populations, one found in the Tuamotu Archipelago and the other in the Society Islands. All three populations were separated from *Leporicypraea mappa viridis* (Kenyon, 1902) by Dr. Felix Lorenz, which he then described as a single new taxon *Leporicypraea mappa admirabilis* Lorenz, 2002. The authors will use analysis of comparative conchological characteristics, biogeographic and oceanographic conditions, and relative genetic change to demonstrate that substantial separation exists to validate *L. m. curvati* as a new subspecies.

**KEYWORDS** Gastropoda, Cypraeidae, *Leporicypraea*, *Leporicypraea mappa curvati*, new subspecies, Marquesas, French Polynesia.

## INTRODUCTION

The Marquesas are an isolated island group located in the far northeastern part of French Polynesia, about 475 km north northeast of the Tuamotu Archipelago, which is itself about 430 km east northeast of the Society Islands. The Marquesas are further isolated by the South Equatorial Current (SEC), which flows due west from the Galapagos Islands and continues through the Marquesas with weak sub-currents and eddies flowing south into the Tuamotu Islands. As volcanic islands, the Marquesas provide a very different habitat compared to the lagoon and fringing reef environments found in the Tuamotu Islands; whereas the Society Islands southwest of the Tuamotu Islands share an interesting mix of biogeographic and oceanographic conditions that provide an environment that might be considered intermediate relative to those found in the Marquesas and Tuamotu Islands. Specific differentiating conchological characteristics will be compared, morphometric results presented, and environmental factors relative to colonization and evolutionary change discussed.

**Abbreviations and Acronyms.**

CM Chris Moe
DL David Lum
FG Frederic Govaert
FL Felix Lorenz
JD John Daughenbaugh
MB Marty Beals
MK Murray Kaufman
PK Paul Kanner
XC Xavier Curvat
SBMNH Santa Barbara Museum of Natural History
L H W - length, height & width
LTct CTct - labral & columellar teeth counted
LTnl CTnl - labral & columellar teeth normalized
mD mR - measured mass & mass ratio

**Material and Methods.**

From the three comparative populations, only mature adult specimens were included for study, with sub-adult, atypical and aberrant specimens being excluded. A total of 27 specimens from Nuku Hiva, Marquesas; 13 from Fakarava, Rangiroa and Takaroa, Tuamotu Islands; and 10 from Tahiti, Society Islands were utilized for comparison of morphological characteristics and measurements.

Comparative measurements enumerated are LxHxW (in mm), LTct : CTct and weight (in grams). For morphometric comparison, the formula **L (W/L-H/L-H/W) LTnl : CTnl [mR]** (Bridges & Lorenz, 2013) was utilized.

All specimens, except the holotype of *L. m. admirabilis* and live animal, were photographed with a tripod-mounted Nikon digital single lens reflex camera. Lens focal length was set at 50 mm or greater to minimize image distortion. Two white fluorescent lamps were used for standard lit imaging and a single ultraviolet (UV) fluorescent lamp for UV lit images. The live animal was photographed with a handheld point-and-shoot digital camera. Adobe Photoshop was utilized for minor image adjustments.

**SYSTEMATICS**

Class Gastropoda
Subclass Orthogastropoda
Superorder Caenogastropoda
Order Sorbeoconcha
Suborder Hypsogastropoda
Superfamily Cypraeoidea
Family Cypraeidae
Subfamily Gisortiinae
Genus Leporicypraea Iredale, 1930

*Leporicypraea mappa curvati*
Beals & Lum, n. spp.
(Figures 1 -3)

**Description.** Shell of medium size (62.5 to 84.6 mm), heavy (mR = 13.6), inflated and pyriform in shape. Dorsum high and distinctly humped, peaking approximately 1/3$^{rd}$ of shell length from the posterior. Ramp between dorsal peak and spire relatively straight when viewed laterally (Figures 1 and 2 depict the holotype). Dorsal base coloration pinkish to lavender grey, overlaid with distinct, dark brown netted pattern, roughly arranged in longitudinal rows. Netting relatively coarse compared to typical western Pacific *L. m. mappa.* Dorsal sulcus line clearly defined, meandering length of shell between centerline and right margin. Spire exsert, partially covered by callus. Margins smooth, callused and somewhat pushed-up towards dorsum. Marginal spots dark brown, distinct to blurred and streaked, wrapping partially onto base. Base convex with pink to lavender cast. Columellar basal blotch large, squarish, and dark purple, extending from peristome, becoming slightly lighter towards margin. Labral basal blotching absent or extremely faint. Aperture narrow and straight, widening somewhat towards anterior. Teeth are distinct and orange. Columellar teeth (CT) fine, short and just reaching base, of nearly equal length, and finest along center third of aperture. Labral teeth (LT) somewhat heavier, extending slightly on to labrum. Fossula steep and concave. Columellar peristome ribbed with light brown interstices. Under ultraviolet light *L. m. curvati* n. ssp. fluoresces bright rosy red.

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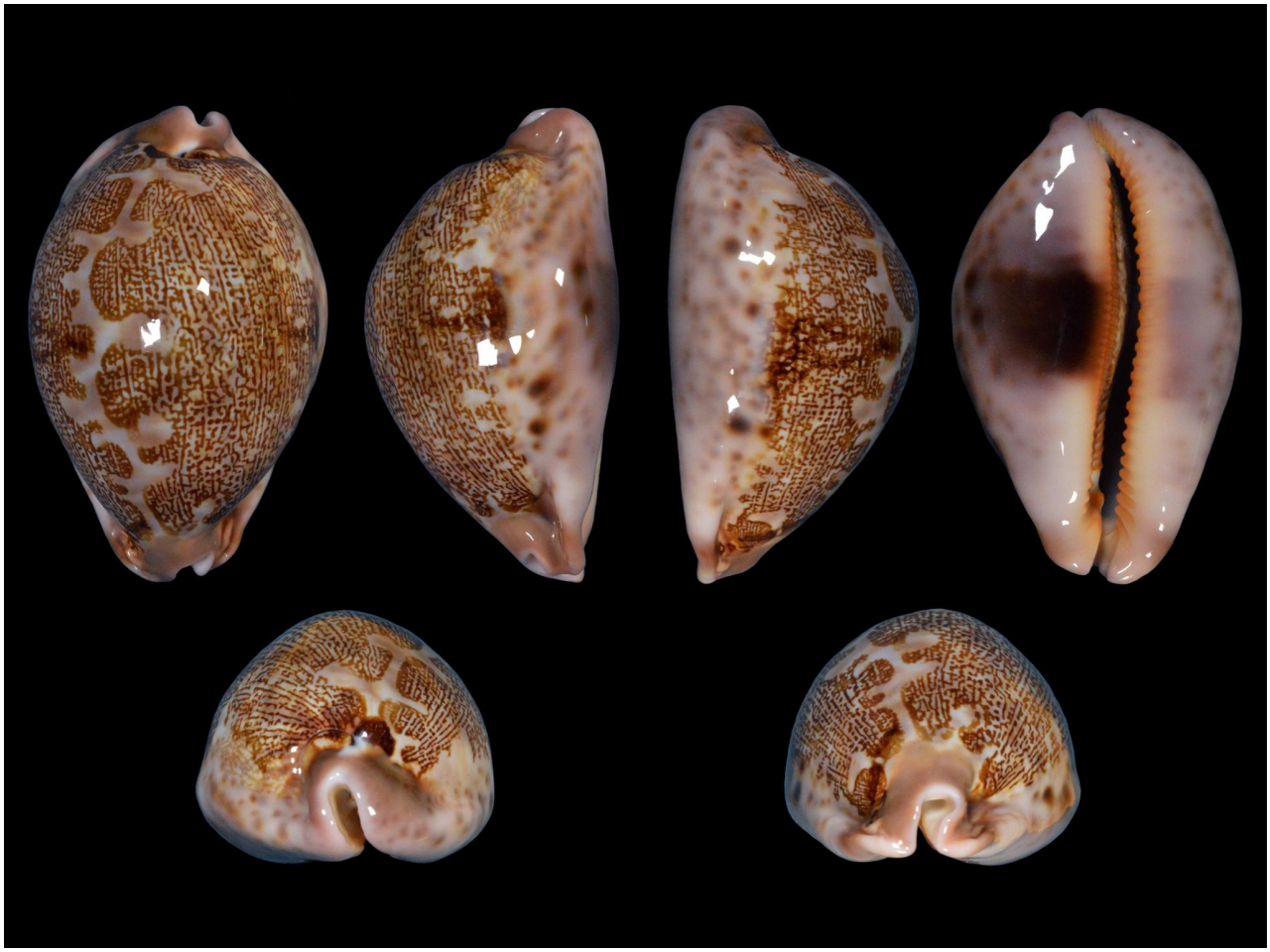

**Figure 1.** *Leporicypraea m. curvati* n. ssp., Nuku Hiva, Marquesas Islands, 72.8 mm, holotype. Photos by D. Lum.

**Type Material.** From the type lot of 27 specimens, the holotype and 18 designated paratypes were selected.

Holotype 72.8x44.9x38.3 (33:33) 52.9 g SBMNH (collection # 162944)

Paratype 1 81.6x55.0x47.0 (34:27) 71.2 g coll. MB
Paratype 2 78.6x49.7x44.4 (39:32) 64.0 g coll. DL
Paratype 3 73.7x46.6x42.1 (36:30) 63.1 g coll. MB
Paratype 4 73.6x46.7x39.3 (35:31) 53.0 g coll. DL
Paratype 5 68.0x43.7x37.6 (35:35) 48.2 g coll. XC
Paratype 6 84.6x53.1x45.2 (36:30) 61.0 g coll. JD
Paratype 7 73.0x44.4x37.4 (39:32) 43.9 g coll. FL
Paratype 8 65.4x41.4x34.2 (24:31) 39.7 g coll. FL
Paratype 9 76.4x48.2x41.6 (36:32) 54.5 g coll. JD
Paratype 10 76.3x49.0x43.2 (39:32) 58.0 g coll. CM
Paratype 11 75.6x50.1x41.7 (39:34) 60.0 g coll. DL
Paratype 12 66.8x43.2x36.6 (33:34) 42.8 g coll. MB
Paratype 13 75.5X47.2x39.0 (34:29) 57.0 g coll. CM
Paratype 14 71.2x44.6x37.6 (32:27) 48.4 g coll. PK
Paratype 15 67.2x44.2x37.9 (29:30) 46.9 g coll. FG
Paratype 16 70.4x45.1x38.0 (33:37) 54.6 g coll. MB
Paratype 17 81.3x53.9x48.5 (35:30) 82.9 g coll. MK
Paratype 18 73.5x46.9x40.2 (38:34) 56.2 g coll. MB

**Type Locality.** The holotype was collected at Taiohae Bay, Nuku Hiva, Marquesas under large rock wedged between boulders at 26 m on a day dive. The 18 designated paratypes and additional 8 type lot specimens were also collected on Nuku Hiva, principally from the southern/Taiohae side between Motumano Point and Controller Bay.

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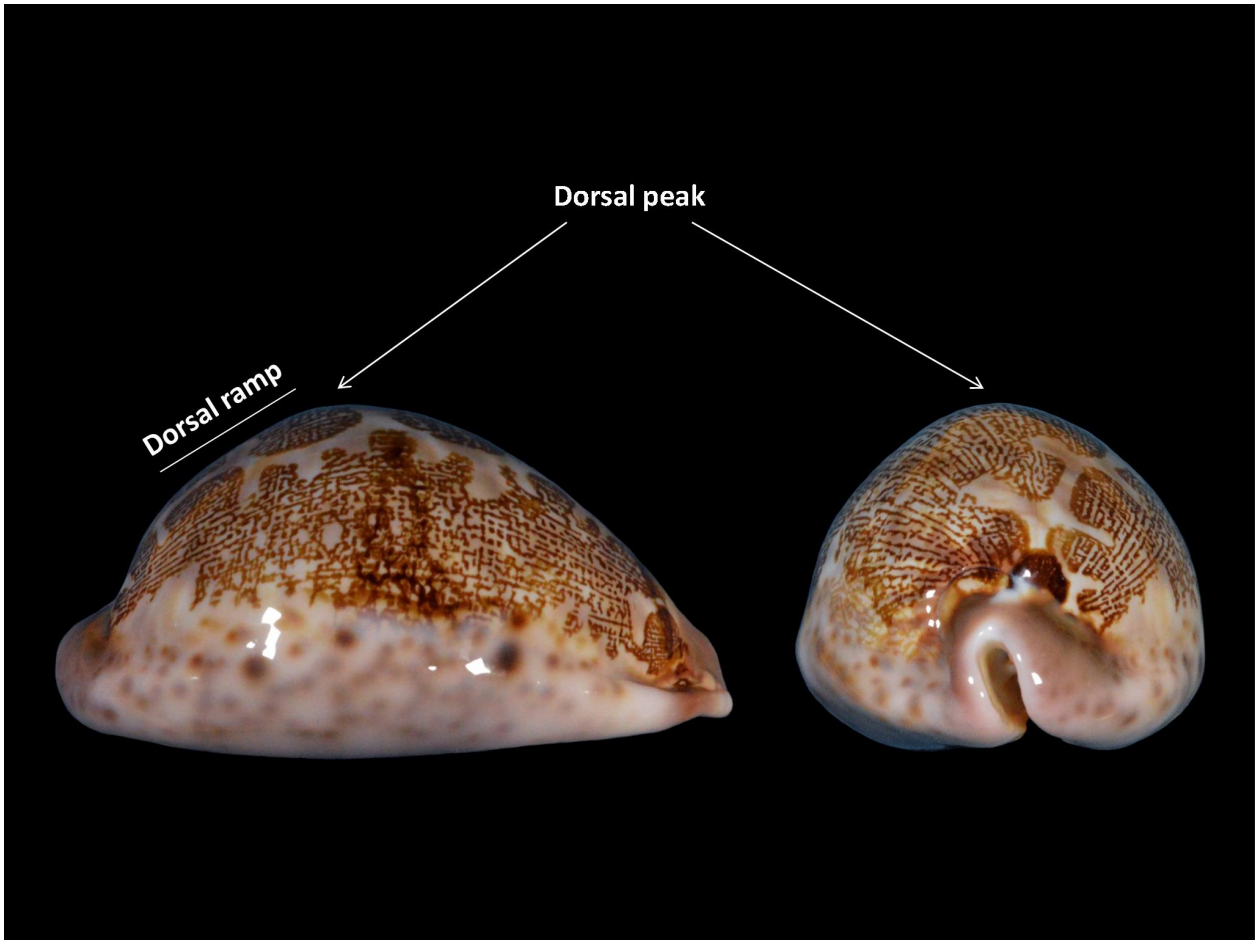


**Figure 2.** Distinguishing characteristics of *L. m. curvati* include a distinct dorsal peak and a relatively straight ramp between spire and peak. These features are lacking or weak in other Polynesian *L. mappa*. Photos by D. Lum.

**Animal Characteristics.** For such a widespread Indo-Pacific group, the animals of the two species and numerous subspecies and forms of the *mappa* complex are remarkably similar, both in comparative morphology and coloration. There are no notable differences in the animal characteristics of the foot, siphon, cephalic tentacles, mantle and papillae, and, at most, only a small degree of variation in coloration. More specific details of morphology and coloration of *L. m. curvati* are best conveyed in the live animal image (Figure 3). Both authors can further confirm the similarity of animal characteristics and coloration from specimens observed while diving in Guam, Marquesas, New Caledonia and the Philippines.

**Habitat and Distribution.** The Marquesas are volcanic islands, providing a very different type of habitat compared to the Tuamotu Islands, which are coral atolls. Steep volcanic rock walls with crevices, ledges and caves, as well as intermittent areas of sloping rock falls, are principal habitats found in the Marquesas. *Leporicypraea m. curvati* is almost exclusively found at night crawling on steep exposed walls, or on cave walls and ceilings. During the day, occasional specimens may be found under large rocks on ledges and sloping rock falls, and also in crevices under rocks wedged between boulders. Though *L. m. curvati* has been found at depths of between 12 and 30 m, it is most frequently observed at 15 to 20 m.

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**Figure 3.** Live specimen of *L. m. curvati*, Nuku Hiva, Marquesas. Photo by X. Curvat.

The Marquesas are an isolated island group located in northeastern French Polynesia, about 475 km north northeast of the Tuamotu Islands and about 1420 km from Tahiti in the Society Islands, which are about 430 km southwest of the Tuamotu Islands. The Marquesas Islands are divided into two groups, the Southern Group of seven islands, and the Northern Group of eight islands which includes Nuku Hiva, the type locality from where all 27 type lot specimens were collected. To date, very few specimens have been located with reliable locality data from islands other than Nuku Hiva. The authors have only been able to confirm additional specimens from Ua Huka (Felix Lorenz, personal communication) and Eiao (Xavier

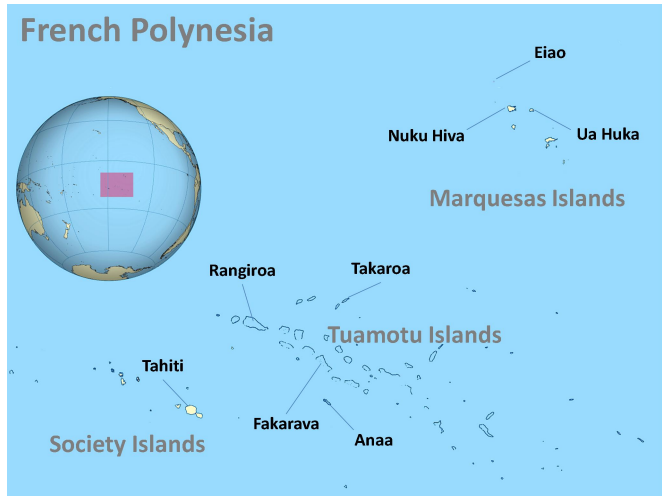


**Figure 4.** Locations where specimens of *L. mappa* referenced in this description were collected. Nuku Hiva, Marquesas Islands is the type locality of *L. m. curvati*. Map by R. Bridges.

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Curvat, personal communication) in the Northern Group and Hiva Oa (Michael Small, personal communication) in the Southern Group. However, aside from Motu One, a coral cay in the Northern Group, with areas of similar habitat and environmental conditions existing in all the other Northern and Southern Group islands, it would be reasonable to surmise *L. m. curvati* is present throughout the Marquesas.

**Etymology.** *Leporicypraea m. curvati* is named in honor of Xavier Curvat. Xavier arrived in the Marquesas from France more than 30 years ago, and not long after started a dive/charter business, which has provided a unique, long term opportunity to accumulate a wealth of information on Marquesan mollusks. However, perhaps of greater importance is the current orientation of his business towards providing services and support for biological and oceanographic research groups.

**Differential Diagnosis.** *Leporicypraea m. curvati* can be readily distinguished from the Society and Tuamotu populations of *L. mappa* by the following key characteristics: a more tumid (inflated) shape; a prominent peak at the dorsal apex located approximately 1/3$^{rd}$ of shell length from the posterior; fewer and much more robust columellar teeth (Figure 6); a relatively wider aperture, particularly towards the anterior; and a lower mass ratio (in other words, a relatively lighter weight shell). In overall shape, *L. m. curvati* is the most inflated taxon, followed by the Society and Tuamotu shells, respectively.

The conchological characteristics of *L. mappa* from the Society Islands are intermediate to the shells from the Marquesas and Tuamotu Islands. While the coloration and markings of the Society shells most closely approach those of the Marquesas specimens, their mass ratio and shapes are closest to those of Tuamotu specimens.

In specific contrast *to L. m. admirabilis* from the Tuamotu Islands, *L. m. curvati* has overall darker coloration and fluoresces a bright rosy red under UV light, while shells from the Tuamotu Islands present only weak fluorescence under UV illumination (Figure 7).

*Leporicypraea m. admirabilis* from the Tuamotu Islands are typically narrow ovate to cylindrical, low profile shells similar to the 73.5 mm holotype and the 68.1 mm specimen shown in Plate 3. The 82.9 mm specimen also depicted in Plate 3 is unusually inflated for a Tuamotu shell. However, its other characteristics are completely consistent with typical *L. m. admirabilis*, particularly the light coloration and, more importantly, the extremely fine columellar teeth.

Table 1 and Figure 5 below provide detailed comparisons between *L. m. curvati* and both populations of *L. m. admirabilis*.

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| Character | *L. mappa curvati* (n=27) Marquesas Islands | *L. mappa admirabilis* (n=13) Tuamotu Islands | *L. mappa admirabilis* (n=10) Society Islands |
|---|---|---|---|
| **Shell shape** | Ovate, inflated, humped dorsal profile | Narrow ovate to cylindrical, lower, more rounded dorsal profile | Medium ovate, less inflated, more rounded dorsal profile |
| **Shell L (avg./range)** | 72.0 (62.5-84.6) mm | 74.0 (59.0-88.4) mm | 74.0 (67.3-81.2) mm |
| **Shell formula = L(W/L-H/L-H/W) LTCn:CTCn[mR]** | 72(63-54-85) 23:22[13.6] | 74(61-51-84) 23:24[14.7] | 74(60-51-85)24:23[14.8] |
| **Normalized labral teeth count (avg./range)** | 23 (18-25, Δ=7) | 23 (18-27, Δ=9) | 24 (21-25, Δ=4) |
| **Normalized columellar teeth count (avg./range)** | 22 (18-25, Δ=7) | 24 (20-27, Δ=7) | 23 (19-25, Δ=6) |
| **Labral teeth characteristics** | Distinct, slightly reaching base | Distinct, slightly reaching base | Distinct, slightly reaching base |
| **Columellar teeth characteristics** | Distinct, slightly reaching base | Indistinct, extremely fine, and small | Fine but distinct, slightly reaching base |
| **Dorsal background color** | Grey to tan with purplish tint | Creamy yellow to tan | Grey to tan with purplish tint |
| **Dorsal netting** | Dark brown rows, clear sulcus line | Light brown rows, clear sulcus line | Dark brown rows, clear sulcus line |
| **Basal color** | Grey with pinkish to purplish tint | Creamy white to lemon yellow | Grey with pinkish to purplish tint |
| **Labral blotch** | Absent to faint | None | Absent to faint |
| **Columellar blotch** | Large, squarish, dark purple | Small to faint, brown | Medium large, squarish, purple |
| **Fluorescence under UV light** | Fluoresces bright rosy red | Weak | Fluoresces bright rosy red |
| **Distribution** | Marquesas Islands | Tuamotu Islands | Society Islands |

**Table 1.** Comparison of *L. m. curvati* n. ssp. to its congeners.

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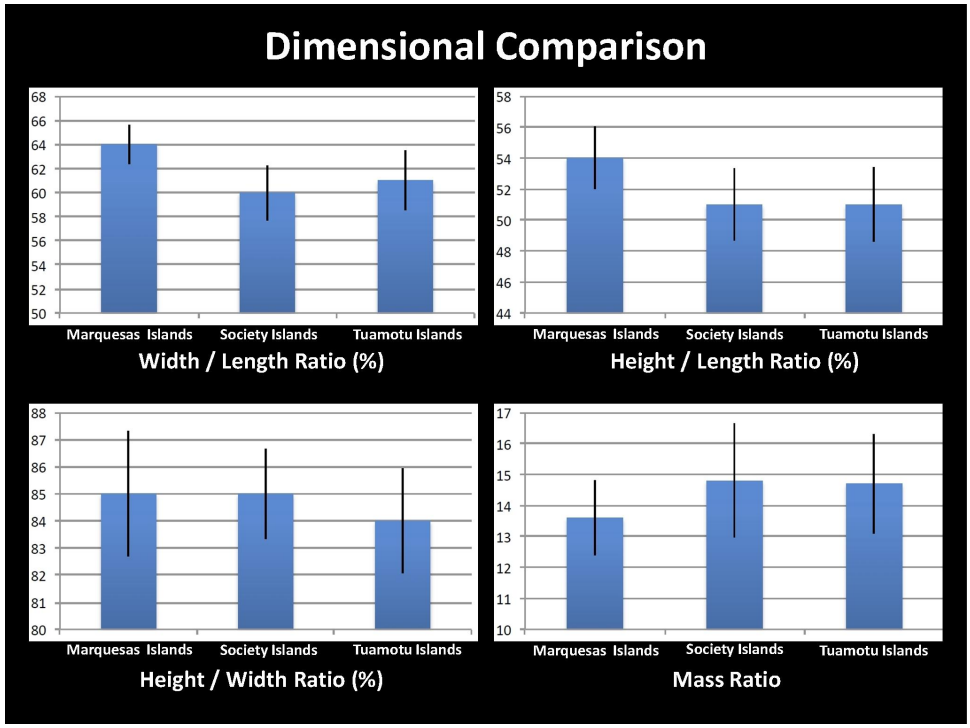


**Figure 5.** Comparison of dimensional and mass ratios of the *L. mappa* populations of the Marquesas, Society Islands, and Tuamotu Islands demonstrates significant morphological differences between them. The shells of *L. m. curvati* (Marquesas) are lighter weight and more inflated. Chart by C. P. Meyer.

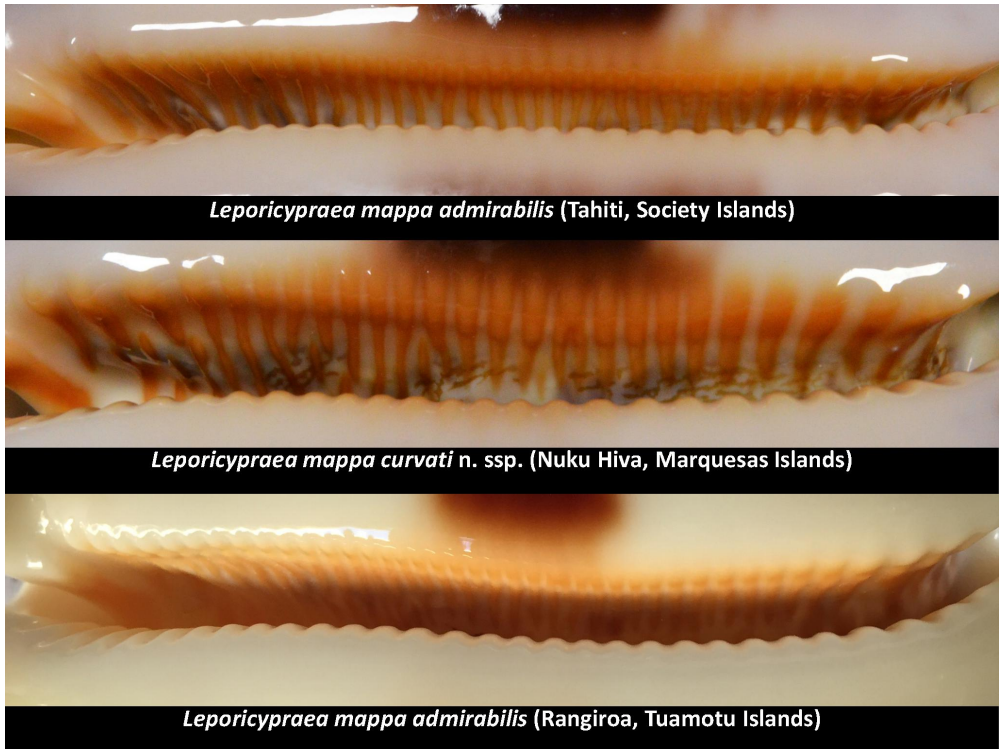


**Figure 6.** Comparison of apertural teeth of *L. m. curvati* and *L. m. admirabilis* (both Society and Tuamotu populations). Note the much more robust columellar teeth of *L. m. curvati*. Photos by D. Lum.

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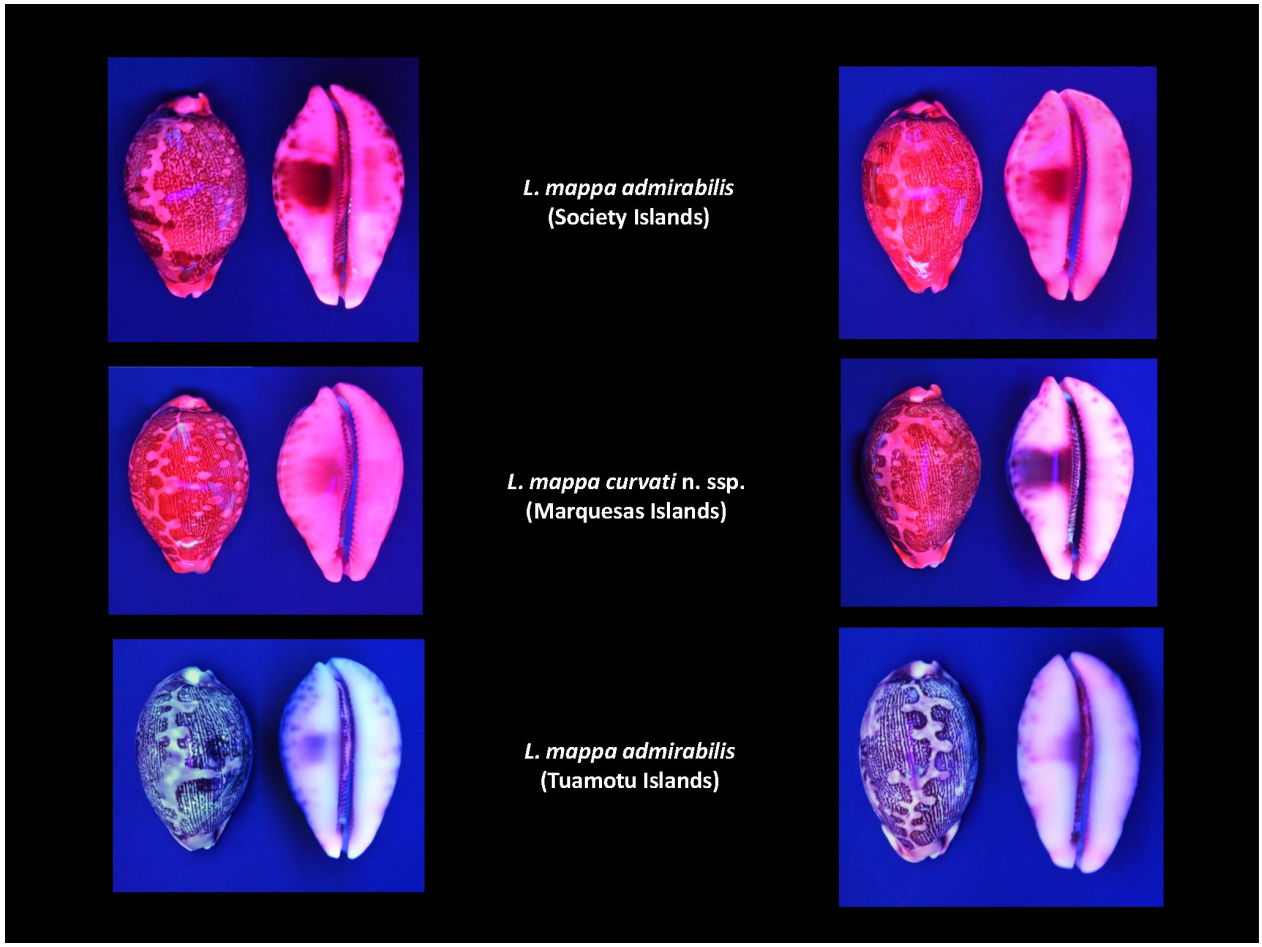


**Figure 7.** French Polynesian *L. mappa* under ultraviolet (UV) light. Note the lack of bright rosy red fluorescence in *L. m. admirabilis* from the Tuamotu Islands. Photos by D. Lum.

## DISCUSSION

The authors follow the hypothesis that the populations of *L. mappa* in French Polynesia originated from an ancestral form of *L. mappa* whose veligers migrated into French Polynesia from the west (Bergonzoni & Passamonti, 2014). Based on genetic evidence from Marquesan *L. m. curvati*, Dr. Christopher Meyer (personal communication) estimates the divergence of *L. m. curvati* from its ancestral form at approximately 3.7 million years before present. This ancestral form may have also given rise to today's *L. m. viridis*, which outside of French Polynesia is geographically and genetically the nearest congener to *L. m. curvati,* and unless genetic sequencing shows otherwise, most probably *L. m. admirabilis* as well. This eastbound colonization to the Marquesas and evolution into separate species and subspecies is evidenced by the existence of closely-related congeners of other Marquesan endemic cowries to the west (*e.g.*, *Erosaria helvola callista* (Shaw, 1909) – *Erosaria helvola bellatrix* Lorenz, 2009, *Cribrarula cumingii* (Sowerby I, 1832) – *Cribrarula astaryi* Schilder, 1971, *Purpuradusta fimbriata unifasciata* (Michaeles, 1845) – *Purpuradusta fimbriata marquesana* Lorenz, 2002, *Mauritia maculifera scindata* Lorenz, 2002 – *Mauritia maculifera martybealsi* Lorenz, 2002, and *Cypraea tigris tigris* (Linnaeus, 1758) – *Cypraea tigris lorenzi*

Meyer & Tweedt, 2017). However, research indicates that the mean time of colonization of these congeners into the Marquesas was much later, at 1.58 million years before present (Hickerson & Meyer, 2008). The separation of the preceding species and subspecies is based not only on discernible differentiating conchological characteristics resulting from parapatric speciation or evolutionary change in founder populations isolated by geographic barriers at the edge of a species range (J. Winston, 1999) and oceanographic conditions, but it is also supported by the work and research put forth on DNA sequencing and separation by Dr. Christopher Meyer (C. Meyer, 2003; 2004). Figure 8 depicts the phylogenetic placement of *L. m. curvati* relative to other members of the genus *Leporicypraea*.

Each of the three island groups in French Polynesia inhabited by *L. mappa* is separated from the others by significant distances. The Marquesas, in far northeastern French Polynesia, are the most isolated, with Nuku Hiva located about 1420 km northeast of Tahiti in the Society Islands and about 1020 km north-northeast of Fakarava in the Tuamotu Islands. In turn, Fakarava is about 430 km east-northeast from Tahiti. These distances, combined with the strong prevailing South Equatorial Current (SEC) which flows due west and effectively separates the Marquesas from the south, prevents any significant introduction of new genetic material from populations in the Tuamotu Islands and Society Islands. However, periodic El Niño-Southern Oscillation (ENSO) events, eddies, and the South Equatorial Counter Current (SECC) have the potential to intermittently distribute veligers from one island group to the others (J. Daughenbaugh, 2015), but given the degree of endemism within each island group, these factors do not appear to be of any significance in interrupting current-ongoing parapatric evolutionary change.

Additionally, the very different marine environments that each population inhabits provide conditions conductive to different adaptations and divergence in morphological characteristics. The Marquesas are volcanic islands, providing a very dissimilar type of habitat compared to the Tuamotu Islands, which are atolls with abundant coral growth. Steep volcanic rock walls with crevices, ledges and caves, as well as intermittent sloping rock fall areas are principal habitats found in the Marquesas. In contrast, ocean-side shallow-sloping coral reef flats and limited inner-lagoon patch reefs are principal habitats found in the Tuamotu Islands. Also, the extremely clear (therefore high light penetration), nutrient-poor and much higher salinity water (resulting from exceptionally low rainfall and high evaporation) in the Tuamotu Islands (Rougerie and Rancher, 1994), may have contributed to special adaptation of *L. m. admirabilis* there and divergence in characteristics as compared to the *L. m. curvati* and the *L. mappa* from the Society Islands. Such divergence might include lighter-colored shells which may better enable them to survive in a well-lit habitat.

Given that oceanographic conditions can change over a significant time frame as a result of such factors as land mass and ocean basin variations due to tectonic movements and the growth and demise of island chains and shallow seamounts, sea level variations due to changes in climate, and ocean current variations driven by climate and geology, many different scenarios could have played out to initially introduce *L. mappa* to French Polynesia. One possible scenario is initial immigration to the Society Islands, the westernmost island group, and after successful colonization there, veligers immigrated northeast to the Tuamotu Islands and then onward finally to the Marquesas. It may even be possible that initial ancestral stock populated all three island groups independently. Regardless

of how colonization began, environmental conditions from at least 11.7 thousand years before present to current day, have effectively isolated the populations of the three major island groups, allowing each to undergo parapatric evolution of characteristics not only unique to each population, but also when compared to all other worldwide *L. mappa* subspecies. Recent research into the genetic signature of *Cypraea tigris* in the Marquesas highlights its significant isolation from all other *C. tigris* populations globally (Meyer & Tweedt, 2017). Given the near ubiquity of *C. tigris* throughout the Indo-Pacific, this provides evidence of very little flow of new Cypraeid genetic material into the Marquesas.

While not the main focus of this paper, which is aimed at defining the Marquesan *L. mappa* as a valid subspecies, the *L. mappa* population of the Society Islands has its own unique set of characteristics that set it apart from those of the Marquesas and Tuamotu Islands. While Lorenz included the Society Island shells in his original description of *L. m. admirabilis* (paratypes 5 and 6), our analysis shows that specimens from this locality display consistent intermediate features to the other populations. Specific highlights include mass ratio and shape, as expressed in ratios between major axial dimensions (length, width, and height) approaching that of Tuamotu shells; apertural teeth, particularly the columellar teeth, more prominent than those of Tuamotu shells but much finer than those of the Marquesan shells; and shell coloration and patterns, including the basal blotch, with some being comparatively close to Marquesan specimens. Coincidentally, the intermediate characteristics of *L. mappa* in the Society Islands is consistent with an environment roughly in-between that of the Marquesas and Tuamotu Islands, but this is only a correlation and a direct link between environment and shell characteristics has yet to be established. For future research, it would be useful to compare the genetic proximity between the three populations to better define their relationship to each other. It is our opinion that the Society Islands population may represent yet a third definable subspecies of *L. mappa* from French Polynesia. Provisionally, until more analysis is conducted, we will continue to accept Lorenz's inclusion of *L. mappa* from the Society Islands as *L. m. admirabilis.*

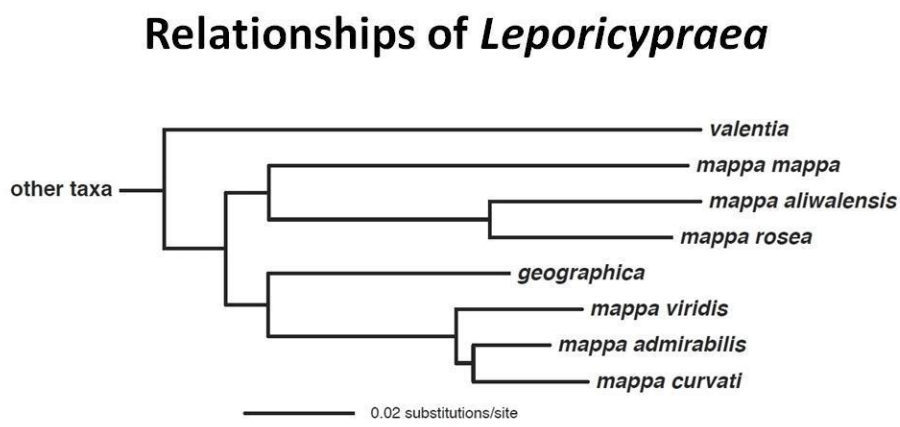


**Figure 8.** Phylogram of the mitochondrial DNA cytochrome oxidase I (mtDNA COI) gene of *Leporicypraea* provided by C. Meyer (personal communication), adapted from Meyer, 2004. *Leporicypraea mappa* from the Society Islands may eventually be proven to be a third *L. mappa* taxon from French Polynesia.

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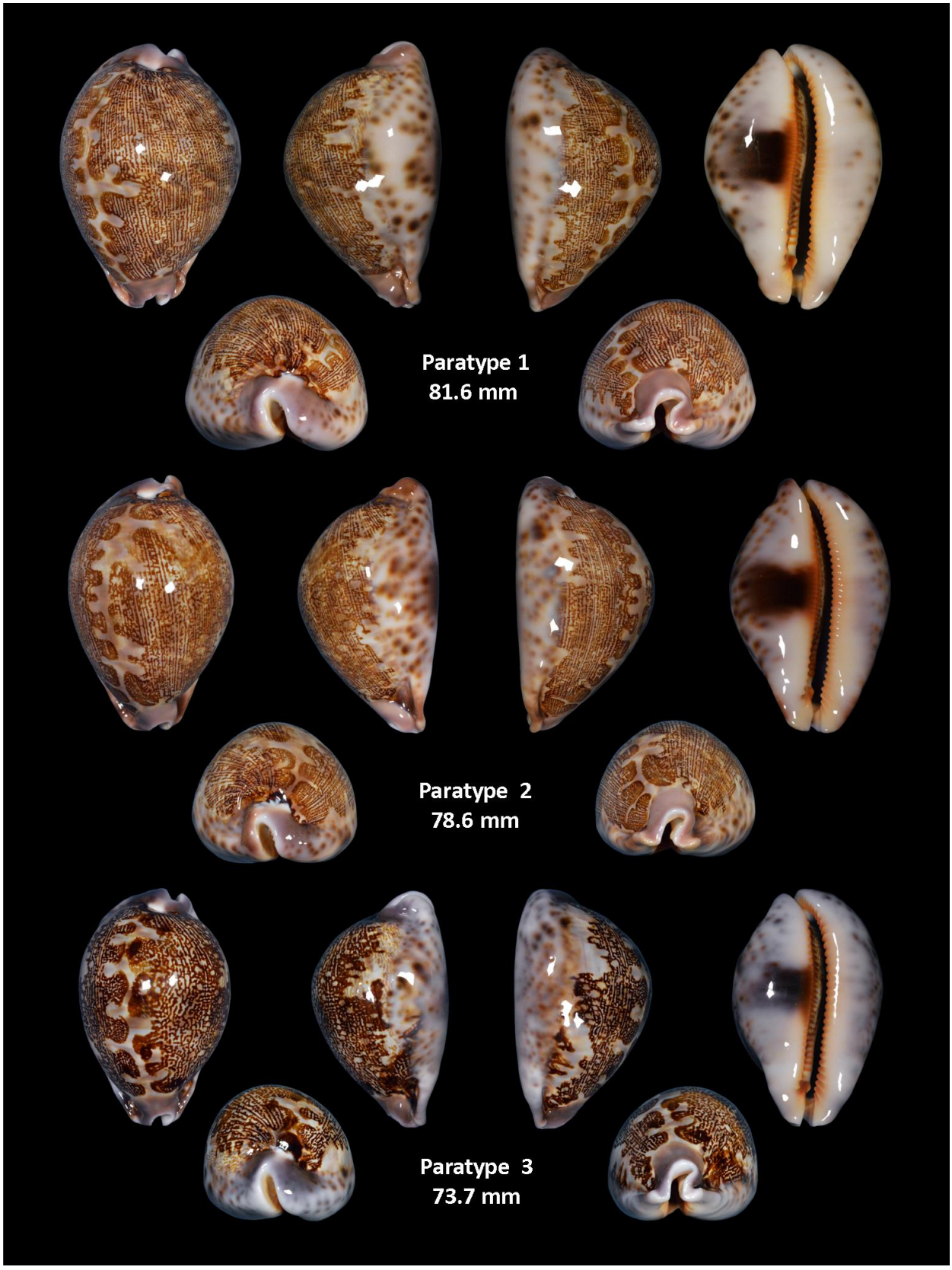


**Plate 1.** *Leporicypraea m. curvati* n. ssp., paratypes from Nuku Hiva, Marquesas Islands. Photos by D. Lum.

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**Plate 2.** *Leporicypraea m. admirabilis* specimens from Tautira, Tahiti, Society Islands. Photos by D. Lum.

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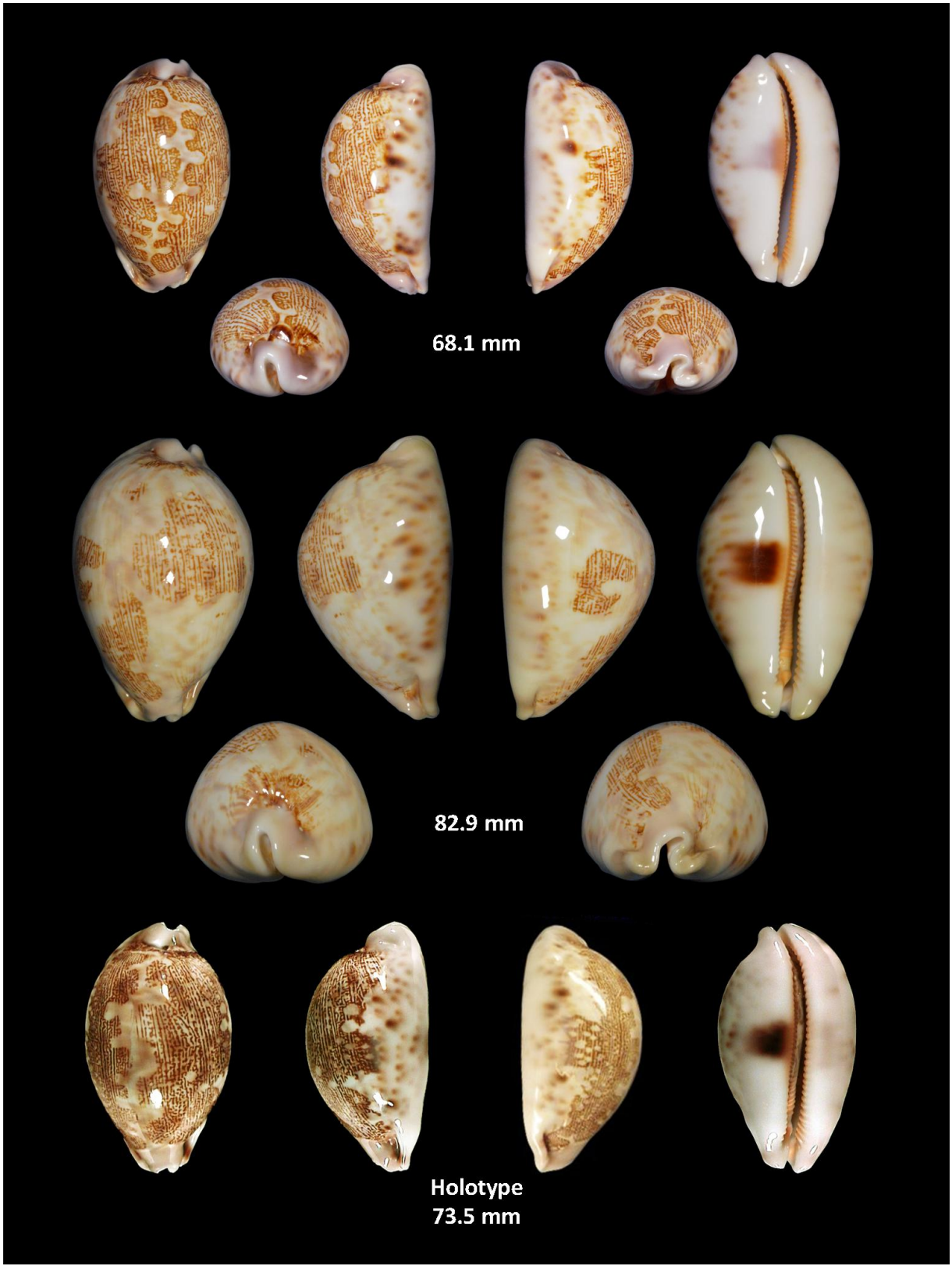


**Plate 3.** *Leporicypraea m. admirabilis* from the Tuamotu Islands (top to bottom Rangiroa, Fakarava, and Anaa). Photos by D. Lum & F. Lorenz (holotype).