Study of the Hawaiian Nucleolaria (Gastropoda: Cypraeidae), with a description of two new species

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Study of the Hawaiian *Nucleolaria* (Gastropoda: Cypraeidae), with a description of Two New Species

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Abstract

Two new species of *Nucleolaria* are described from the Hawaiian Islands on the basis of conchological characters. *Nucleolaria hinuhinu* n.sp. resembles *granulata* (Pease, 1862), but has a glossy shell with fewer basal ribs. *Nucleolaria pseudonucleus* n.sp. is conchologically closer to *nucleus* (Linnaeus, 1758), but it differs by its slightly more inflated shell with more uniform dorsal nodules and a wider anterior canal.

Introduction

C. M. Burgess collected, in the mid-1940's, the first known live specimen of *Nucleolaria nucleus* (Linnaeus, 1758) in Hawaii (Kay & Weaver, 1963). Burgess (1985) states that only two or three live specimens, and perhaps half-dozen beach worn were known from Hawaii by the mid-1980's. With the increase in popularity of scuba diving more specimens have since come to light.

Nucleolaria granulata (Pease, 1862) and *cassiaui* (Burgess, 1965) are the only known extant cowries to have a dull and rough shell when fully adult. However, the juvenile (Figs 19–21) has a glossy shell, but it is thin-walled, lighter in color, the basal ridges are few and not well formed, and the dorsal nodules small, compared to those of adults. As the juvenile matures (Figs 22–24), there are remarkable changes in the shell, from glossy and smooth to the touch to dull and rough; the white base in the juvenile changes to beige or rosy brown, the basal ridges thicken, and intercalary ribs are deposited (Figs 13–18). Burgess (1960a) explains that only beach-worn shells of *granulata* may become shiny. However, Dayle (1990) documented the first live-collected glossy "grannie." A short color video now available on YouTube (Dayle, 2007) shows the same specimen from 1990, live and labeled a "cross-breed" between *granulata* and *nucleus*. Lorenz & Hubert (2000) also mention Hawaiian intergrades. Hawaiian collectors have informally called such specimens "hapa" (Hawaiian for mixed race).

For over four years this author has gathered information and material of Hawaiian *Nucleolaria* Oyama, 1959 to investigate specimens similar to the glossy *granulata*-like shell reported by Dayle (1990). Thanks to the efforts of Chris Takahashi and many diver friends from the Hawaiian Malacological Society, enough material has been assembled to study the Hawaiian *Nucleolaria*: 34 shells previously identified as *nucleus* or *nucleus* x *granulata*; 66 *granulata*, 62 *nucleus* (s.l.) from outside of Hawaii, including specimens identified as *nucleus gemmosa* (Perry, 1811) and *nucleus madagascariensis* (Gmelin, 1791), and 1 *cassiaui*. Most specimens were borrowed from private collections and museums; about one third of the material studied is in the author's collection.

Upon closer inspection, it became evident that *Nucleolaria* represents a complex of cryptic species, with at least two unnamed morphotypes in Hawaii. One of the morphotypes is conchologically closest to *granulata*, while the other is closest to *nucleus*. Both are herein described as new species, based on conchological characters.

Abbreviations

ANSP – Academy of Sciences, Philadelphia; BD – Bob Dayle coll.; CT – Chris Takahashi coll.; DL – David Lum coll.; DW – David Watts coll.; FM – Fabio Moretzsohn coll.; FMNH – Field Museum of Natural History; HMNS – Houston Museum of Natural Science; JAF – Joe AuFranz coll.; MP – Mel Pang coll.; MS – Mike Severns coll.; USNM – U.S. National Museum, Smithsonian Institution.

Nucleolaria hinuhinu n. sp.

Type material (Figs 1–12)**:** Holotype (Figs 1-6): ANSP 423878, shell size (mm): 24.27 x 16.38 x 11.70; 13/22 (columellar/labral teeth), from Oahu, Makaha, 90 ft, collected and donated by C. Takahashi. Paratypes (22): Oahu: USNM 1135986, Pearl Harbor, 1 shell, donated by F. Moretzsohn; CT, Mokuleia, 60-65 ft, 2 shells; CT, Lahi Point, 115 ft, 1 shell; JAF, West side, 8-10 m, 1 shell; CT, Ft. Kamehameha, 20 ft, 1 shell; JAF, Ft. Kamehameha, 30 ft, 2 shells; DW, Makaha, 30 ft, 2 shells; JAF, Makaha, 20 ft, 1 shell; DL, Waimea, 39-50 ft, 2 shells; DL, Oahu, 1 shell; FM 1867, North Shore, 1 shell; BD GRA110, North Shore, 1 shell; BD GRA143, North Shore, 1 shell (Figs. 7–12); FM 1889, Ewa Beach, 1 shell. Maui: DW, 25 ft, 1 shell; MS 244, Kihei, 60 ft, 2 shells. Hawaiian Islands: MP, 1 shell.

Type locality: Makaha, Oahu, Hawaii (approx. 21°28'7"N, 158°13'8"W) (Fig. 57).

Diagnosis: Shell oval rostrate, with dorsal nodules, marginal and basal ridges glossy and smooth to the touch.

Description: Shell ranging in length from 21.68 to 32.36 mm (ave. 25.33 mm), ovate, with rostrate extremities and canals with pointed tips. Shell width/length ratio 66.1% and shell height/width ratio 70.4%. Dorsum with elevated dorsal nodules closely spaced, and strung on ridges, especially on the left side, that continue to the margins and onto the

base. Basal ridges strong, reaching the aperture, both on the base and labrum; intercalated ribs thinner, rarely reaching columella, while those on the labrum may reach aperture. Aperture narrow, curved, with strong teeth (15.6 columellar and 21.3 labral teeth average). Basal ridges, intercalated ribs and dorsal nodules often lined in red-brown in fresh specimens. Dorsal coloration ranges from rosy-brown to brown, but sometimes much lighter ("blonde"). Dorsal groove straight or nearly straight, well impressed; dorsal line (groove) angle 81.8° (average).

Animal: No preserved animals were available for anatomical or molecular studies. However, photos of live specimens (by B. DAYLE and D. LUM) (Fig. 58) show that the animal resembles that of *granulata*, although perhaps more brightly colored, with long, tubular papillae that bear short thorn-like projections.

Habitat: Under ledges, in lava tubes, or under rocks or corals, between 6 to 35 m (av. 13.7 m).

Distribution: Currently known only from the main Hawaiian Islands; most specimens studied were from around Oahu (Fig. 57).

Etymology: The epithet *hinuhinu* is a noun in apposition, derived from the Hawaiian word "Hinuhinu" meaning "glossy, shining, lustrous, glittering, as of polished stones or shells" (PUKUI & ELBERT, 1986), in allusion to its smooth shell. The proposed vernacular name is "Glossy Granulated Cowrie."

Comparison: *Nucleolaria hinuhinu* n.sp. is conchologically closest to *granulata*; the main differences (Table 1) from it include a glossy shell that is smooth to the touch, a less dorso-ventrally compressed (depressed) shell with rostrate extremities, fewer columellar teeth, slightly fewer intercalated basal ribs, and often, more rounded marginal calluses. The dorsal line angle (*sensu* MORETZSOHN, 2002) is slightly higher in *hinuhinu*, meaning that the lobes of the mantle meet closer to the mid dorsum. *N. hinuhinu* differs from *nucleus* and *pseudonucleus* by its larger, broader, and more depressed shell, with a more distinct and deeper dorsal groove, higher dorsal line angle, fewer columellar and labral teeth, and by having the dorsal part of the anterior canal more horizontal (i.e. not convex).

Table 1: Comparison of shell characters. Items in bold represent some of the major differences from other taxa. Measurements in mm.

Character	*hinuhinu* n. sp	*granulata*	*pseudonucleus* n. sp.	*nucleus nucleus*
Shell shape	Oval rostrate	Oval, depressed	Oval inflated	Oval elongated
Shell L (ave/range)	25.33 (21.68-32.36)	26.41 (18.82-38.80)	20.27 (17.22-23.75)	21.88 (17.48-26.13)
Shell W/L (%) (ave./range)	66.1 (60.9-70.9)	67.6 (59.5-74.8)	63.00 (61.3-67.3)	61.0 (56.1-67.8)
Shell H/W (%) (ave./range)	70.4 (64.6-78.5)	67.7 (59.9-79.4)	79.3 (73.8-85.5)	81.0 (76.3-84.0)
Columellar teeth (reduced)	15.6 (13-19)	17.5 (13-23)	16.6 (14-19)	17.6 (15-22)
Labral teeth (reduced)	21.3 (18-24)	21.3 (19-24)	22.9 (20-26)	24.1 (22-27)
Intercalated basal ribs	9.8 (7-14)	10.3 (7-14)	9.3 (7-12)	9.2 (3-14)
Marginal callus	rounded/keeled	sharply keeled	rounded	rounded/keeled
Dorsal color	cream to brown	light brown/rosy brown	cream to light brown	cream to light brown
Dorsal nodules density	high	high	high, nodules small, uniform	medium-high; uneven sizes
Dorsal nodules gloss	shiny	dull	shiny	shiny
Dorsal nodules interspace	shiny	dull	shiny	shiny
Basal color	lighter than dorsum	beige, as dorsum	same as dorsum	cream
Basal ridge gloss	shiny	dull	shiny	shiny
Basal interspace gloss	shiny/dull	dull	dull	dull
Marginal ridges gloss	shiny	dull	shiny	shiny
Marginal interspaces gloss	shiny	dull	shiny	dull
Shell feel to touch	smooth	rough	smooth	smooth
Extremities rostration	rostrate	blunt	rostrate	rostrate
Ant. canal diameter/W (%)	12.3 (9.3-17.0)	11.6 (8.3-15.2)	13.5 (10.6-16.4)	13.4 (10.7-15.4)
Dorsal groove	distinct	distinct	less distinct	less distinct
D.L. angle (ave./range)	81.8 (80-90)	78.0 (70-90)	79.1 (70-85)	75.5 (65-85)
Spire blotch/callus	white, small	white	white, small to med	white, v. small
Apertural teeth lining color	light to medium brown	brown	light brown	light brown/none
Ant. end flared dorsally	horizontal	horizontal	convex	convex
Distribution	Hawaiian Islands	Hawaiian Islands	Hawaiian Islands	Red Sea, Indo-Pacific
Schilder's formula	25.66.21.15	26.68.21.17	21.62.23.16	22.61.24.18
New formula*	24.9/66.2/15.3/12.3/4.3	26.4/67.7/17.5/11.6/4.3	20.3/63.0/16.6/13.5/5.1	21.9/61.0/17.6/13.4/5.2

* 1) Shell L; 2) W/L ratio; 3) ave. CT (reduced); 4) anterior canal diameter/W ratio (%); 5) labral spot diameter/L ratio (%). Note that this formula was slightly modified from MORETZSOHN (2002).

Figures 1–12. *Nucleolaria hinuhinu* n. sp. **1–6.** Holotype, ANSP 423878, Oahu, Makaha: 24.27 mm. **7–12.** Paratype 19, BD GRA143, Oahu, North Shore: 26.42 mm.

Figures 13–30. *N. granulata*. **13–18.** FM 728, Oahu: 24.65 mm. **19–21.** FM 1669, Oahu, North Shore: 22.32 mm, juvenile. **22–24.** FM 1669, Oahu, North Shore: 23.69 mm, subadult (note white base without intercalary ribs). **25–30.** FMNH 85697, Hawaiian Islands: 28.90 mm, "skinny" morphotype.

Nucleolaria pseudonucleus n. sp.

Type material (Figs 31–42; 45–50)**:** Holotype (Figs 31–36): ANSP 425050, shell size (mm): 21.29 x 13.25 x 10.48; 19/24, from Oahu, Makua, 40 ft, on sponge in lava cave; donated by F. Moretzsohn. Paratypes (10): Midway: FMNH 159984, 1 shell (Figs 37–42). Oahu: BD GRA064, Makua, 1 shell; JAF, Kaena Point, 35 ft, 1 shell; DW, Makaha, 30 ft, 2 shells; MP, Makaha, 15 ft, 1 shell; FM 1748, North Shore, 20-60 ft, 1 shell. Big Island: JAF, Kona, 9 ft, 1 shell. Hawaiian Islands: FMNH 77718, 2 shells (Figs 45–50).

Type locality: Makua, Oahu, Hawaii (approx. 21°32'02"N; 158°13'56"W) (Fig. 57).

Diagnosis: Shell oval inflated, rostrate, with large anterior canal, and dorsal nodules of about uniform size.

Description: Shell ranging in length from 17.22 to 23.75 mm (av. 20.27 mm), oval with rostrate extremities and canals with pointed tips. Shell width/length ratio 63.0% and shell height/width ratio 79.3%. Dorsum with many small nodules of uniform size, connected by ribs that continue onto the base. Basal ridges strong, reaching the aperture, both on the base and labrum; intercalated ribs thinner, rarely reaching the aperture. Aperture narrow, curved, with strong teeth (16.6 columellar and 22.9 labral teeth average). Basal ridges, intercalated ribs and dorsal nodules often lined in light brown in fresh specimens. Anterior canal diameter/shell width ratio 13.5%. Dorsal coloration ranges from grayish-cream to light brown, with basal color similar. Dorsal groove not very distinct; dorsal line angle 79.1° (average).

Animal: No live or preserved specimens were available for study, but they have been collected by divers, who reported the animal to be similar to that of *nucleus* observed in other locales in the Indo-Pacific.

Habitat: Under ledges, in lava tubes, or under rocks, between 2.7 to 12.2 m (av. 8.6 m).

Distribution: Currently known only from the Hawaiian Islands, ranging from Midway to the Big Island (Fig. 57); most specimens studied were collected around Oahu.

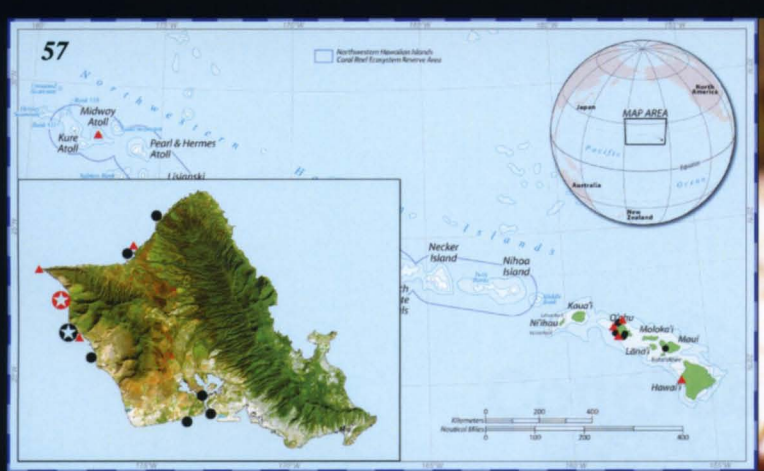
Etymology: The epithet *pseudonucleus* is a noun in apposition, in reference to its *nucleus*-like shell. The proposed vernacular name is "False Nuclear Cowrie."

Comparison: *Nucleolaria pseudonucleus* n. sp. is conchologically closest to *N. nucleus nucleus*, and differs by having a slightly smaller shell that is broader (higher W/L ratio) (Table 1) and more inflated, with fewer columellar and labral teeth. The dorsal nodules in *pseudonucleus* appear to be in higher number and more uniform in size than in *nucleus*, and the dorsal line angle is higher than in *nucleus*. *N. pseudonucleus* can be easily separated from *granulata* and *hinuhinu* by its smaller, narrower and less dorsal-ventrally compressed shell, and by having a wider anterior canal, with the dorsal part of the anterior canal convex; unlike *granulata*, its shell is glossy and smooth to the touch.

Discussion: Despite interest from collectors, the Hawaiian *Nucleolaria* species complex has been neglected by taxonomists. Burgess probably did not help, by affirming categorically, in reference to *granulata*, that "a live-collected fully adult shiny shell does not exist. The polish was put there by sand and wave action on the beach!" (Burgess, 1960). Therefore, in the last 50 years, collectors followed Burgess' advice, and thought that any shiny *granulata*-like shells were just beach-worn or not fully-grown *granulata*. Hence the importance of Dayle (1990)'s discovery of a live shiny specimen, which proves that a fully adult *granulata*-like shell can be glossy. Once the material for this study was put together, it became clear that these glossy shells were not mere variations, but that there are consistent differences from *granulata*, despite intraspecific variation. The most striking difference is in the feel of the texture, which in *hinuhinu* is smooth as in typical *nucleus*, while in fresh, fully mature *granulata*, the shell feels rough and the nodules sharp. Another difference is the gloss of dorsal nodules, marginal and basal ridges, and sometimes, interspaces. However, the amount of gloss varies (e.g., the holotype of *hinuhinu* is not very glossy), and can be difficult to capture on a photograph, since not all dorsal nodules, interspaces, basal ridges, etc. may reflect light evenly from all angles. The best way to reveal the gloss is to examine the shell under bright lights, such as an LED ring with many lights, and manipulate the shell, changing the angle of light incidence, causing many little reflections to appear on different parts of the shell. However, beware of mineral oil, sometimes used by collectors, which can make a true *granulata* appear shiny; washing the shell with warm water and mild soap will remove the oil, and only the natural gloss will remain. This author suggests that naturally dull shells like *granulata*, should not be covered in oil.

Lorenz & Hubert (2000) mention Hawaiian "intergrades" that may refer to *hinuhinu*. *N. pseudonucleus* n.sp. is rarely collected live, and the typical *nucleus nucleus* seems to be even rarer in Hawaii, although there are genuine records (e.g. Figs. 43–44; Burgess, 1960b–the top right shell; the top left appears to represent *hinuhinu*; Kay, 1979). Some of the previous records identified as "*nucleus*" from Hawaii may actually refer to *pseudonucleus*. A third morphotype (Figs. 25–30), resembling *granulata*, with rough texture but with a narrow, more elongate and less dorso-ventrally depressed shell was also indentified; it may represent interspecific variation or perhaps sexual dimorphism in *granulata*. Further investigation is needed, including field observations and anatomical studies, to verify whether it represents sexual dimorphism, or if it represents yet another unnamed taxon.

The late Pleistocene fossils (from about 26,000 years ago) from Oahu reported as *nucleus* (Cross, 1971) and "hapa" (C. Takahashi, pers. comm., 2009) may represent *pseudonucleus*; however, no positive identification can be made from



Figures 31–48: *Nucleolaria pseudonucleus* n. sp. **31–36.** Holotype, ANSP 425050, Oahu, Makua: 21.29 mm. **37–42.** Paratype 1, FMNH 159984, Midway Atoll: 20.08 mm. **43–48.** Paratype 2, FMNH 77718, Hawaiian Islands: 18.68 mm. **49–50.** *N. nucleus*, MS 298, Hawaii, Puako: 23.18 mm. **51–56.** *N. nucleus*, FM 1875, Philippines: 23.24 mm. **57.** M ap of Hawaii showing the distribution of *Nucleolaria hinuhinu* (black dots) and *N. pseudonucleus* (red triangles). The star within a circle (✪) indicates the type localities; **58)** *Nucleolaria hinuhinu* n. sp., live specimen collected by D. Lum © 2006.

the photos, so it remains to be corroborated. The presence of fossils suggests that *nucleus* has colonized the Hawaiian Islands at least since the late Pleistocene, and probably before that (although there are no known earlier fossils). The warmest interglacial period and maximum marine transgression during the Pleistocene occurred about 120,000 years ago (KOHN, 1980), which produced emerged reefs common around Hawaii. Warmer ocean temperatures allowed veliger larvae of tropical species to colonize the Hawaiian Islands. The late Pleistocene Hawaiian marine fauna is similar to the Recent fauna; some of those now extinct locally are currently found in more tropical areas (CROSS, 1971).

In Hawaii, the *Nucleolaria* complex is the result of biogeography: multiple colonizations by a single species, the widespread *nucleus* over geologic time, followed by periods of isolation, leading to founder effect and genetic drift. *Nucleolaria pseudonucleus* is conchologically closer to *nucleus nucleus*, so perhaps it represents a more recent colonization than *hinuhinu*. The conchological differences found on the shells of these taxa may be the result of single mutations, e.g. in a gene that causes the animal to produce a rough shell when mature in *granulata*; in both *hinuhinu* and *pseudonucleus*, the animal continues to produce a glossy shell, like in its parental population. Future studies of preserved material, from Hawaii and elsewhere, are needed to corroborate the taxa proposed here. Since populations of both taxa are sympatric with two congeneric species in Hawaii, they are described as species, instead of subspecies. Once people start to look into museums and private collections more carefully, certainly new specimens of both species will surface.

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Moretzsohn, F. 2011. Study of the Hawaiian Nucleolaria (Gastropoda: Cypraeidae), with a description of two new species. Pp. 515–520 (Appendix 3) in Severns, M. *Shells of the Hawaiian Islands – The Sea Shells. The Verifiable Species and Their Described Variants*. ConchBook, Hackemhein, Germany.

Errata: The table below was printed in Mike Severns' book without boldface type that was meant to emphasize which characters are the most important in identifying each species.

Table 1. Comparison of shell characters. Items in bold represent some of the major differences from other taxa. Measurements in mm.

Character	***hinuhinu* n.sp**	***granulata***	***pseudonucleus* n.sp.**	***nucleus nucleus***
Shell shape	**Oval rostrate**	Oval, depressed	Oval inflated	Oval elongated
Shell L (ave/range)	25.33 (21.68–32.36)	26.41 (18.82–38.80)	20.27 (17.22–23.75)	21.88 (17.48–26.13)
Shell W/L (%) (ave./range)	66.1 (60.9–70.9)	67.6 (59.5–74.8)	63.00 (61.3–67.3)	61.0 (56.1–67.8)
Shell H/W (%) (ave./range)	**70.4 (64.6–78.5)**	67.7 (59.9–79.4)	79.3 (73.8–85.5)	81.0 (76.3–84.0)
Columellar teeth (reduced)	**15.6 (13–19)**	17.5 (13–23)	**16.6 (14–19)**	17.6 (15–22)
Labral teeth (reduced)	21.3 (18–24)	21.3 (19–24)	**22.9 (20–26)**	24.1 (22–27)
Intercalated basal ribs	9.8 (7–14)	10.3 (7–14)	9.3 (7–12)	9.2 (3–14)
Marginal callus	**rounded/keeled**	sharply keeled	rounded	rounded/keeled
Dorsal color	cream to brown	light brown/rosy brown	cream to light brown	cream to light brown
Dorsal nodules density	high	high	**high, nodules small, uniform**	medium-high; uneven sizes
Dorsal nodules gloss	**shiny**	dull	shiny	shiny
Dorsal nodules interspace	**shiny**	dull	shiny	shiny
Basal color	lighter than dorsum	beige, as dorsum	same as dorsum	cream
Basal ridge gloss	**shiny**	dull	shiny	shiny
Basal interspace gloss	**shiny**/dull	dull	dull	dull
Marginal ridges gloss	**shiny**	dull	shiny	shiny
Marginal interspaces gloss	**shiny**	dull	shiny	dull
Shell feel to touch	**smooth**	rough	smooth	smooth
Extremities rostration	**rostrate**	blunt	rostrate	rostrate
Ant. canal diameter/W (%)	12.3 (9.3–17.0)	11.6 (8.3–15.2)	13.5 (10.6–16.4)	13.4 (10.7–15.4)
Dorsal groove	distinct	distinct	less distinct	less distinct
D.L. angle (ave./range)	**81.8 (80–90)**	78.0 (70–90)	**79.1 (70–85)**	75.5 (65–85)
Spire blotch/callus	white, small	white	white, small to med	white, v. small
Apertural teeth lining color	light to medium brown	brown	light brown	light brown/none
Ant. end flared dorsally	horizontal	horizontal	convex	convex
Distribution	Hawaiian Islands	Hawaiian Islands	Hawaiian Islands	Red Sea, Indo-Pacific
Schilder's formula	25.66.21.15	26.68.21.17	21.62.23.16	22.61.24.18
New formula*	24.9/66.2/15.3/12.3/4.3	26.4/67.7/17.5/11.6/4.3	20.3/63.0/16.6/13.5/5.1	21.9/61.0/17.6/13.4/5.2

* 1) Shell L; 2) W/L ratio; 3) ave. CT (reduced); 4) anterior canal diameter/W ratio (%); 5) labral spot diameter/L ratio (%). Note that this formula was slightly modified from Moretzsohn (2002).