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A new species of *Haliotis* (Gastropoda) from São Tomé & Príncipe Islands, Gulf of Guinea, with comparisons to other *Haliotis* found in the Eastern Atlantic and Mediterranean

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Abstract

The Haliotidae from the Gulf of Guinea, West Africa are reviewed. The distribution of the mainland species *Haliotis marmorata* Linnaeus, 1758 is confirmed and compared to the insular species from the island nation of São Tomé and Príncipe which is described as *Haliotis geigeri* n. sp. Both species are illustrated and compared to the other known Haliotidae from the eastern Atlantic.

Key words: Gastropoda, Haliotidae, Eastern Atlantic, Africa

Introduction

The Gulf of Guinea represents an important tropical marine biodiversity hotspot in the Eastern Atlantic Ocean, particularly the isolated oceanic volcanic islands of Annobón, São Tomé, and Príncipe (Jones 1994; Roberts *et al.* 2002). These islands form the oceanic crustal extension of the Cameroon Volcanic Line, a 1600 km long chain of volcanoes that extends from Annobón in the southwest to the African continental volcanoes of the Western Cameroon Highlands in the northeast (Lee *et al.* 1994; Marzoli *et al.* 2000). The Gulf of Guinea is geologically and biogeographically complex and while taxonomic research on the marine fauna remains rather limited, a number of recent studies provide a better understanding of this marine ecoregion (Wirtz *et al.* 2007; Carrison-Stone *et al.* 2013). These biological surveys and studies note a marine fauna characterized by relatively low endemism and a high proportion of ampho-Atlantic species (i.e., reef fish, decapods, and asteroids) associated with the eastern flowing Equatorial Current and widespread Eastern Atlantic species that may extend from northwestern Africa (and associated islands) to Angola (i.e., reef fish and nudibranchs; Wirtz 2003, 2004; Wirtz *et al.* 2007; Floeter *et al.* 2008; Wirtz & d'Udekem d'Acoz 2008). While endemism is low for some of the groups in the Gulf of Guinea, the marine invertebrate fauna of São Tomé & Príncipe contains a number of endemic genera, species, and subspecies including several taxa within the Archaeobalanidae, Marginellidae, and Muricidae (Gofas & Fernandes 1988; Rólan & Fernandes 1991; Carrison-Stone *et al.* 2013).

Here I describe a new species of *Haliotis* endemic to the islands of São Tomé & Príncipe. Currently, *Haliotis marmorata* Linnaeus, 1758 is the only recognized species of abalone located in the Gulf of Guinea and occurs in Ivory Coast, Ghana, Bioko Island (Equatorial Guinea), and Gabon (Geiger & Owen 2012). This species belongs to a clade that has a propensity to develop narrowly distributed insular taxa (Geiger & Owen 2012). This clade dominates the Eastern Atlantic and also includes the widespread North Atlantic and Mediterranean *Haliotis tuberculata* Linnaeus, 1758, the eastern and central Mediterranean *Haliotis mykonosensis* Owen, Hanavan & Hall, 2001, and the northwestern African *Haliotis speciosa* Reeve, 1846 (Geiger & Owen 2012).

The island nation of São Tomé & Príncipe is considered a major conservation priority due to its isolation, coral reefs, species richness, marine invertebrate endemism, and increased environmental threat levels (Jones 1994; Roberts *et al.* 2002). The continued discovery of new endemics highlights the biological and ecological significance of these islands' marine fauna and the need for their protection and conservation.

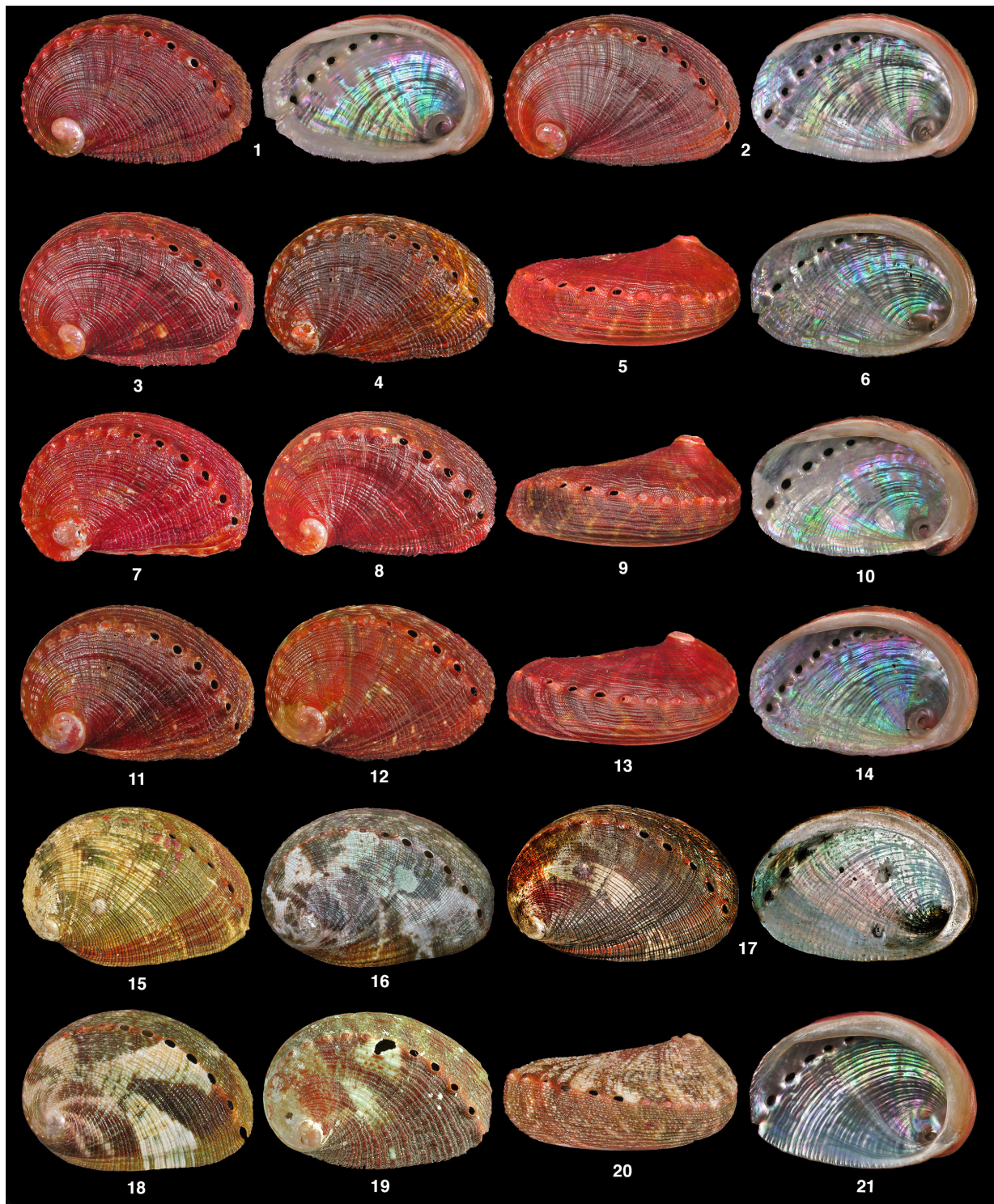


FIGURE 1. 1–14. *Haliotis geigeri* n. sp. São Tomé and Príncipe Islands. 1. Gamboa Beach, São Tomé Island, 37.3 mm, holotype, SBMNH 425150. 2. From type locality, 37.4 mm, paratype, BOC 149. 3. From type locality, 35.5 mm, paratype, SBNHM 425213. 4. From type locality, 38.8 mm, paratype, SBMNH 425213. 5. Lagoa Azul Beach, São Tomé Island, 30.0 mm, BOC 150. 6. From type locality, 38.8 mm, paratype, SBMNH 425213. 7. From type locality, 34.5 mm, paratype, SBMNH 425213. 8. From type locality, 33.5 mm, paratype, MNHN-IM-2012-2725. 9. Between São Tomé City and Boca do Inferno, São Tomé Island, 34.8 mm, BOC 162. 10. From type locality, 33.5 mm, paratype, MNHN-IM-2012-2725. 11. From type locality, 31.0 mm, paratype, CASIZ 196007. 12. Lagoa Azul Beach, São Tomé Island, 29.5 mm, paratype, NMNZ M.316161. 13. Lagoa Azul Beach, São Tomé Island, 35.6 mm, BOC 152. 14. From type locality, 31.0 mm, paratype, CASIZ 196007. 15–21. *Haliotis marmorata*. 15. Takoradi, Ghana, 68.6 mm, BOC. 16. Syntype *H. rosacea* Reeve, 1846, Hab. Unk. 45.1 mm, NHMUK 1950.3.16.12–14. 17. Syntype, West Africa, 62.5 mm, LSL 579. 18. Madrachmi Point, Ghana, 30.0 mm, BOC. 19. Libreville, Cap Esterias, Gabon, 28.3 mm, MNHN. 20. Nzema Cape, Ghana, 36.5 mm, BOC. 21. Western Region, Ghana, 35.5 mm, BOC.

Abbreviations of collections. BOC: Buzz Owen Collection, Gualala, California, USA; SBMNH: Santa Barbara Museum of Natural History, Santa Barbara, California, USA; APC: Aaron Pan Collection, Amarillo, Texas, USA; ARC: Arjay Raffety Collection, Marina del Rey, California, USA; MNHN: Muséum nationale d'Histoire Naturelle, Paris, France; NMNZ: Museum of New Zealand Te Papa Tongarewa, Wellington, New Zealand; NHMUK: The Natural History Museum, London, UK; LSL: Linnean Society London, UK; OCC: Olivier Caro Collection, France.

Shells examined. *Haliotis geigeri* n. sp., São Tomé and Príncipe Island, 31; *H. marmorata* Linnaeus, 1758, Ghana region to Gabon, West Africa, 47; *H. speciosa* Reeve, 1846, Dakar Region to Morocco, >100; *H. tuberculata coccinea* Reeve, 1846, Canary Islands; Azores and Madeira Islands, >100; *H. tuberculata fernandesi* Owen & Afonso, 2012, Cape Verde Islands, 18; *H. tuberculata tuberculata* f. *lamellosa* Lamarck, 1822, Aegean and Adriatic Seas, >7000; *H. tuberculata tuberculata* Linnaeus, 1758, Brittany, France, and the British Isles, >500. Other species examined: *H. mykonosensis* Owen, Hanavan & Hall, 2001, Aegean and Mediterranean Seas, >200; *H. stomatiaeformis* Reeve, 1846, Mediterranean Sea, >200.

Genus *Haliotis* Linnaeus, 1758

Type species. *Haliotis asinina* Linnaeus, 1758 (subsequent designation Montfort, 1810)

Haliotis geigeri n. sp.

(Figs. 1.1–14, 2)

Type material. Holotype: SBMNH 425150 (Fig. 1.1), 37.3 mm. Paratype #1: BOC 149 (Fig. 1.2), 37.4 mm, from type locality. Paratypes #2–4: SBMNH 425213 (Fig. 1.3), 35.5 mm, (Fig. 1.4, 1.6), 38.8 mm, (Fig. 1.7), 34.5 mm, from type locality. Paratype #5: MNHN-IM-2012-2725 (Fig. 1.8, 1.10), 33.5 mm, from type locality. Paratype #6: CASIZ 196007 (Fig. 1.11, 1.14), 31.0 mm, from type locality. Paratype #7: NMNZ M.316161 (Fig. 1.12), 29.5 mm, from Lagoa Azul, São Tomé Island, 0°24'23"N, 06°36'39"E.

Additional specimens: BOC 150–161, 29.2–36.8 mm, from type locality. BOC 162, 34.8 mm, between São Tomé City and Boca do Inferno, São Tomé Island. APC, 31.0 mm, 39.0 mm, from Lagoa Azul Beach, São Tomé Island. OCC, 30.0 mm, 36.0 mm, from type locality. MNHN, 23.5 mm, 30.0 mm, from Calypso, 1956, Stn. 88, Ilot Caroco, Príncipe Island; 27.8 mm, 29.4 mm, from Praia Emilia, São Tomé Island; 32.7 mm, from Praia das Conchas, Guadalupe, São Tomé Island; 33.2 mm, from Praia Mouro Peixe, Guadalupe, São Tomé Island.

Type locality: Gamboa Beach, São Tomé Island; 0°22'45"N, 06°43'3"E.

Etymology: The name of this species honors Daniel L. Geiger for his extensive and continued study of the Haliotidae and the major contributions he has made and continues to make to the *Haliotis* literature.

Habitat: All specimens were live-taken by diving between 5–20 m on coral and rocky reef structures, and/or were found dead lying on sand or silt in between dead coral and stones. No animals have been preserved or examined.

Description: Shell small (to approximately 41 mm), fairly light-weight, oblong, hardly arched, somewhat convex. Anterior margin straight to slightly curved. Spire highly elevated, exposed, tilted, located approximately 27% from posterior margin of shell (Figs. 1.1–14, 2); partially visible in ventral view (Fig. 1.1–2). Shell wrapping around spire. Holes medium sized, slightly elevated, somewhat elongate, usually 5–6 open. Faint to moderately strong bright red line often running through row of holes. Dorsal surface relatively smooth, with spiral ribs varying from very narrow to medium in width, often with fine, somewhat weak but sharply cut lines intersecting and crossing ribs. Periphery between tremata and columella usually with 8–10 ribs; the 4–5 closest to holes often quite narrow, with remaining ribs considerably wider (Fig. 1.5, 9, 13). Uppermost wider rib separating these areas, often somewhat raised forming slight ridge. Columella narrow. Shell usually uniformly bright red to reddish-brown; occasionally marked with small white irregular patch or patches, or with several tiny streaks of white; approximately 5% of material marked with patches of chocolate brown, light green, light tan and/or red. Proscloine rays absent. Diet banding usually not evident; slightly different shade of red when present. Ventral surface iridescent silver nacre with reflections of pink, green, blue; often quite smooth or with weak spiral ribbing barely

visible on most specimens. Some shells with opaque patches probably caused by being cleaned with chlorine solution. No muscle scar.

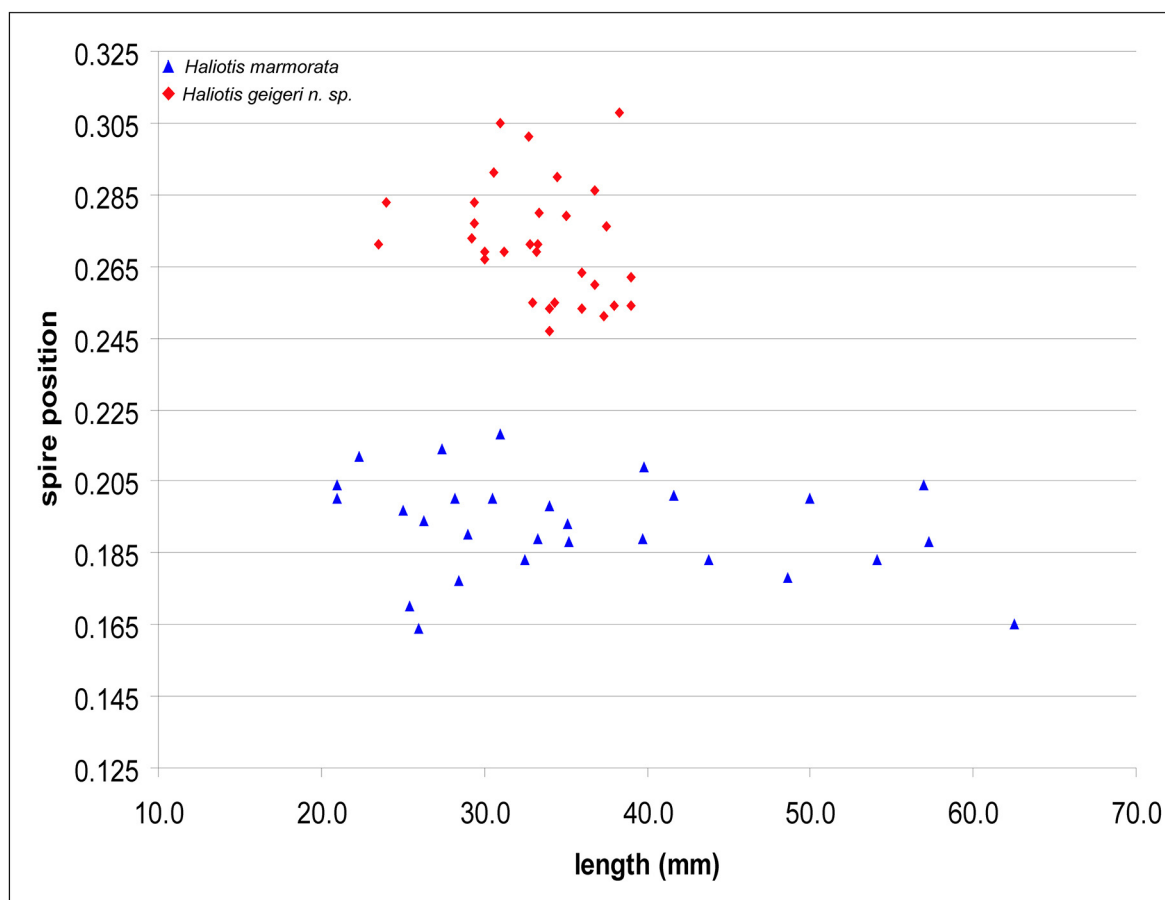


FIGURE 2. Spire position (proportion from posterior end compared to shell length) as a function of size. *Haliotis marmorata* and *H. geigeri n. sp.*

Comparisons. *Haliotis marmorata* (Fig. 1.15–21) can reach sizes in excess of 50 mm (largest examined 76.8 mm), is usually marked with large patches of white arranged in an irregular manner, and may have prosocline rays in early stages of growth. The spire is more flattened and the shell frequently wraps around it to a greater degree. Additionally, the spire is located approximately 19% from the posterior margin of shell, and the shell is proportionately slightly wider (Figs. 1.15–21, 2). The anterior margin is rounded and the shell usually has a wide columella. Evidence of diet banding was found in 12 of 47 specimens examined—usually of green coloration (Fig. 1.15). The shell has narrow sharply etched spiral ribbing with strong lines intersecting and crossing the ribs, producing an almost file-like effect, and ribbing shows strongly in ventral view. Typically 15–20 fine spiral ribs can be found between the tremata and columella, though this number can vary: shells over 55 mm may have as many as 25–28.

Haliotis tuberculata tuberculata (Fig. 3.1–4) has a rounded anterior margin, is usually heavily marked with patches of green and cream, and often has weak to fairly strong lamellae-like folded ridges. The spire is located approximately 14% from the posterior margin of shell. The shell size is large, often reaching an excess of 100 mm on the Atlantic coast of France and Brittany.

Haliotis tuberculata coccinea (Fig. 3.5–8) has very strong spiral ribbing, which is visible in both dorsal and ventral views. The shell is elongate and the spire is located approximately 15% from the posterior margin. The shell is frequently marked with extremely strong and variable patches of red, brown, white, and tan arranged in random order, though uniformly colored specimens also occur, generally of a brown or reddish tone. The subspecies can attain a size in excess of 80 mm.

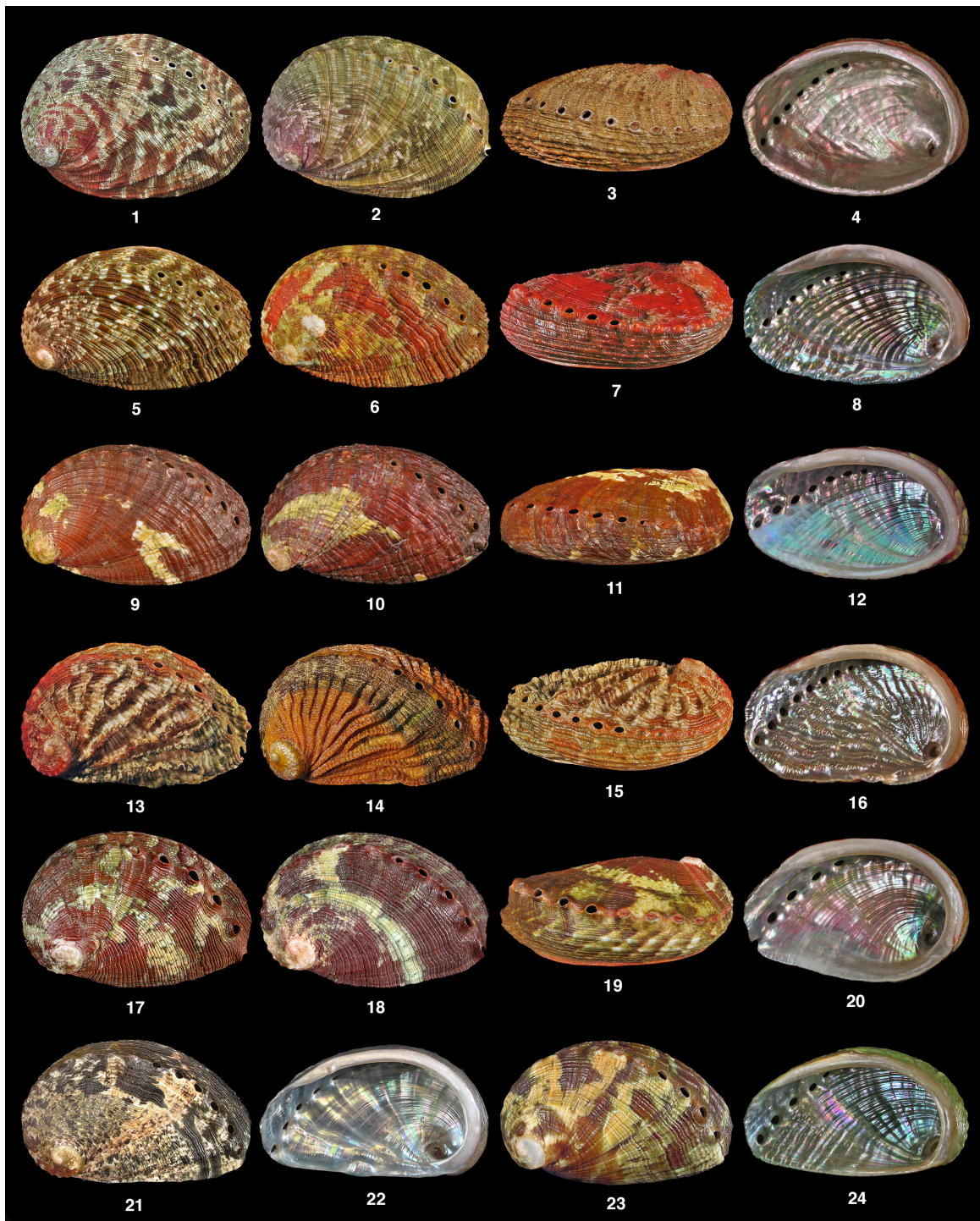


FIGURE 3. 1–4. *Haliotis tuberculata tuberculata*. 1. Guernsey, Channel Islands, UK, 120.0 mm, ARC. 2. Quiberon, Brittany, France, 104.8 mm, BOC. 3. Ile de Groix, Brittany, France, 105.2 mm, BOC. 4. Guernsey, Channel Islands, UK, 115.0 mm, ARC. 5–8. *H. tuberculata coccinea*. 5. San Juan de la Rambla, Tenerife Island, Canary Islands, Spain, 75.4 mm, BOC. 6. Santa Cruz de la Palma, Isla de la Palma, Canary Islands, Spain, 34.3 mm, BOC. 7. Puerto de las Nieves, Gran Canaria, Canary Islands, Spain, 35.6 mm, BOC. 8. San Juan de la Rambla, Tenerife Island, Canary Islands, Spain, 75.4 mm, BOC. 9–12. *H. tuberculata fernandesi*. 9. Sal Island, Cape Verde Islands (CVI), 41.4 mm, BOC. 10. Paratype, Sal Island, CVI, 53.2 mm, BOC. 11. Matiota, São Vicente Island, CVI, 48.8 mm, BOC. 12. Sal Island, CVI, 41.4 mm, BOC. 13–16. *H. tuberculata tuberculata* form *lamellosa*. 13. Platy Yialos, Mykonos, Greece, 43.5 mm, BOC. 14. Straccoligno Bay, Capoliveri, Elba Island, Italy, 38.6 mm, BOC. 15. Straccoligno Bay, Capoliveri, Elba Island, Italy, 40.4 mm, BOC. 16. Platy Yialos, Mykonos, Greece, 48.5 mm, BOC. 17–20. *H. speciosa*. 17. Pointe des Almadies, Senegal, 61.0 mm, BOC. 18. Dakar, Senegal, 36.2 mm, BOC. 19. Pointe des Almadies, Senegal, 58.5 mm, BOC. 20. Pointe des Almadies, Senegal, 58.5 mm, BOC. 21–22. *H. mykonosensis*. 21. Platy Yialos, Mykonos, Greece, 42.7 mm, BOC. 22. Platy Yialos, Mykonos, Greece, 46.6 mm, BOC. 23–24. *H. stomatiaeformis*. 23. Bahar-ic-Caghaq, Malta, 32.0 mm, BOC. 24. Saint Thomas Bay, Malta, 32.1 mm, BOC.

Haliotis tuberculata fernandesi (Fig. 3.9–12) is elongate, frequently of a red-purple coloration, and has weak spiral ribbing. The spire is located approximately 12% from the posterior margin and is not visible in ventral view. It is generally marked with irregular flammules or patches of a wax yellow color.

Haliotis tuberculata tuberculata form *lamellosa* (Fig. 3.13–16) has a variable number of strong lamellae in addition to having medium-width scaly spiral ribs. It is marked with varied patterns of a wide variety of colors including orange, red, yellow, brown and black. The shell has a brilliant silver nacreous interior, which is highly irregular and lumpy due to very jagged sculpture on dorsal surface.

Haliotis speciosa (Fig. 3.17–20) has numerous white to greenish white flammules and irregular patches, has 4–5 quite large, elevated and slightly elongate open holes, and possesses a wider columella. It tends to lack the red line connecting the holes, and is a much larger species, occasionally attaining a length over 70 mm.

Comparisons made to other species found nearby in the Mediterranean Sea. *Haliotis mykonosensis* (Fig. 3.21–22) has different color patterns and tent markings of mixed colors of white, brown, orange, green, tan and occasionally almost black. Uniformly colored specimens of orange and green (rare) also exist as well as banded specimens of brown and orange. Specimens of a similar red color to *H. geigeri* are not known.

Haliotis stomatiaeformis (Fig. 3.23–24) is more elongate with a spire located approximately 15% from the posterior end of shell. Usually has 4 (occasionally 5) open holes located closer to the anterior margin. Colors are highly variable with irregular blotches and patches of green, brown, white, wax yellow, red, and tan. Almost uniformly orange specimens are known, but no entirely red specimens.

Remarks. Spire position appears to be diagnostic and ontogenetically invariant since similarly sized individuals of *Haliotis geigeri* and *H. marmorata* do not overlap in this characteristic (Fig. 2).

The significant morphological differences between the new species and its continental neighbor are likely due to its isolation from the African mainland populations, separated by the Gabon Basin with depths of 2000–3500 m and a horizontal distance of between 200–250 km. São Tomé & Príncipe, while geographically close to the continent, has been isolated from the mainland since the initial oceanic archipelago formed in the Oligocene, around 31 million years ago (Lee *et al.* 1994).

Haliotis rosacea Reeve, 1846, is a synonym of *H. marmorata*. None of the syntypes are conspecific with *H. geigeri*. One of the syntypes was figured by Reeve (1846: pl.16, no. 60) and has the color pattern, spire position, and red line running through the holes indicative of *H. marmorata*. In addition, the types, located at NHMUK, do not bear resemblance to *H. geigeri* and clearly represent *H. marmorata*. In addition, *Haliotis guineensis* Gmelin, 1791 is also likely a synonym of *H. marmorata*. Gmelin's original type material has been lost and no illustrations are known. However, based on the stated geographic provenance of his material (Ghana), Gmelin's species likely represented *H. marmorata*.

Additional specimens of each species have been illustrated by Geiger & Owen (2012).

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