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Hawaiian Cypraeidae

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INTRODUCTION

More is known of the natural history of the Hawaiian Cypraeidae than is known of this family of mollusks from any other single geographical unit in the world. Its fossil distribution and the evolution of certain species have been discussed by Ostergaard (9, 10).[1] Schilder (12) has discussed statistically species which are principally from Pearl and Hermes Reef, Laysan Island, and French Frigate Shoal. Harris (2) has presented valuable information concerning the giant individuals of *Cypraea tigris* Linnaeus found in Hawaii. I have provided an accurate check list with specific distributional records on the species found in the Hawaiian Islands, discussed the relationships of the five endemic species (3, 4, 5), and have commented (6) on Schilder's paper (12). Spicer (14) has discussed the importation of shells from Guam for sale on Midway.

Twenty-nine species of Cypraeidae have been reported from Hawaii by me (4). Of this number five, *Cypraea sulcidentata* Gray, *C. tesellata* Swainson, *C. semiplota* Mighels, *C. ostergaardi* Dall, and *Nucleria madagascariensis* Gmelin, are endemic. Possibly *C. gaskoini* Reeve should likewise be considered endemic, but further data from neighboring islands are needed to show its endemicity to Hawaii.

Inaccurate data concerning the occurrence of Cypraeidae in Hawaii have been reported by Bryan in his Natural History of Hawaii (1). Bryan credits *Cypraea arabica* Linnaeus to Hawaii, and states that the endemic cowry *Nucleria madagascariensis* Gmelin, "Is a wide-ranging form . . ." Schilder and Schilder (13) have likewise attributed species of cowries to Hawaii which are not found here. Other inaccurate

[1] Numbers in parentheses refer to Literature Cited, page 23.

distributional data have been reported in a mimeographed bulletin of the minutes of the Conchological Club of Southern California in an article which was in great part paraphrased from one of my papers (4).

In the future great care should be used by those studying Cypraeidae in crediting cowry records to Hawaii based on shells purchased or obtained from non-scientific collectors and Hawaiian curio stores. Kenyon and I (6, 7, 8) have pointed out the danger of accepting distributional records based on shells which have been informally collected and indiscriminately distributed during the war. Spicer (14) has aptly reported the importation of Guam shells to Midway Island to be sold to construction workers. The Guam shells which have been sold as Hawaiian on Midway and which are not found in the Hawaiian cowry fauna are *C. annulus* Linnaeus, *C. caurica* Linnaeus, *C. intermedia* (= *depressa* of Gray), *C. argus* Linnaeus, *C. mappa* Linnaeus, and *C. arabica* Linnaeus.

This paper closes some of the gaps in our knowledge of Hawaiian cowries and attempts to summarize information already published. The following natural history phases of the Hawaiian Cypraeidae are discussed: variation in color and size in individuals of a species, the immature stages in the shell development of certain species, and conditions under which species live and where they are found. Diagnostic characters enabling one immediately to separate species are included under each species. A brief discussion of the use of cowry shells by Hawaiians is included.

The specimens upon which a large part of the data included here are based are housed in Bishop Museum and in the collections of J. M. Ostergaard, Ditlev Thaanum, T. T. Dranga, and in my collection.

I wish to acknowledge with deep gratitude the aid and suggestions received from Dr. Charles Howard Edmondson of Bernice P. Bishop Museum, and to thank Mr. Karl Kenyon of Mills College for taking a great number of the photographs.

HAWAIIAN CYPRAEIDAE FOUND AS FOSSILS

The following species have been reported from the late Pleistocene of the Hawaiian Islands by Ostergaard (9, 10):

Cypraea caputserpentis Linnaeus: common, Oahu, Molokai
Cypraea carneola Linnaeus: rare, Oahu, Molokai
Cypraea cruenta Gmelin: rare, Oahu
Cypraea erosa Linnaeus: medium, Oahu

Cypraea gaskoini Reeve: very rare, Oahu
Cypraea helvola Linnaeus: common, Oahu, Molokai; rare, Maui
Cypraea isabella Linnaeus: common, Oahu; rare, Molokai
Cypraea mauritiana Linnaeus: very rare, Oahu
Cypraea reticulata Martyn: rare, Oahu
Cypraea scurra Chemnitz: very rare, Oahu
Cypraea sulcidentata Gray: rare, Molokai
Cypraea talpa Linnaeus: very rare, Oahu
Cypraea teres Gmelin: very rare, Oahu
Cypraea tesellata Swainson: medium, Oahu; rare, Molokai
Cypraea vitellus Linnaeus: very rare, Oahu
Nucleraria madagascariensis Gmelin: medium, Oahu, Molokai
"Pustularia" cicercula (Linnaeus): rare, Oahu

Fossils of the following species have not yet been found in the Hawaiian Islands: *Cypraea arenosa* Gray, *C. fimbriata* Gmelin, *C. lynx* Linnaeus, *C. rashleighana* Melvill, *C. tigris* Linnaeus, *C. ostergaardi* Dall, *C. poraria* Linnaeus, *C. semiplota* Mighels, *Nucleraria nucleus* (Linnaeus), *"Pustularia" annulata* (Gray). Further intensive collecting will probably reveal other species in Hawaii, for there are a number of as yet unexplored fossil beds.

SIZE VARIATION IN HAWAIIAN CYPRAEIDAE

A total of 1,200 mature individuals of Hawaiian Cypraeidae were measured to show variations in length, width, and height. Table 1 summarizes the extreme variations in size of the specimens studied. Species showing the greatest variation from the largest to the smallest individuals in length, width, and height are *Cypraea mauritiana* Linnaeus with a 48 mm. variation in length, a 37.50 mm. variation in width, and a 26.40 mm. variation in height; *C. sulcidentata* Gray with a 40.85 mm. variation in length, a 21 mm. variation in width, and a 23 mm. variation in height; and *C. carneola* Linnaeus with a 57.50 mm. variation in length, a 30.75 mm. variation in width, and a 26.25 mm. variation in height. The species showing the least variation from the largest to the smallest in length, width, and height are *C. fimbriata* Gmelin with only a 4.40 mm. variation in length, a 2 mm. variation in width, and a 2.10 mm. variation in height, and *C. poraria* Linnaeus with only a 6.50 mm. variation in length, a 6 mm. variation in width, and a 3 mm. variation in height.

Table 1.—Extreme Variations in Some Hawaiian Cypraeidae

Species	Length Extremes	Difference	Width Extremes	Difference	Height Extremes	Difference
carneola	88-30.50 mm.	57.50 mm.	50.50-19.75 mm.	30.75 mm.	43.25-17 mm.	26.25 mm.
mauritiana	96-48 mm.	48 mm.	69-31.50 mm.	37.50 mm.	49-22.60 mm.	26.40 mm.
sulcidentata	69-28.15 mm.	40.85 mm.	40-19 mm.	21 mm.	39-16 mm.	23 mm.
tigris	147-117 mm.	30 mm.	92-77 mm.	15 mm.		
isabella	43.50-15 mm.	28.50 mm.	24-7.50 mm.	16.50 mm.	20.50-6 mm.	14.50 mm.
madagascariensis	42-18 mm.	24 mm.	25-12.50 mm.	12.50 mm.	18-11 mm.	7 mm.
talpa	68-44 mm.	24 mm.	36.50-24 mm.	12.50 mm.	30.20-19.80 mm.	10.40 mm.
helvola	31-9 mm.	22 mm.	21-9 mm.	12 mm.	15-7 mm.	8 mm.
reticulata	68-46 mm.	22 mm.	46-31 mm.	15 mm.	35.20-23.25 mm.	11.95 mm.
caputserpentis	37-17 mm.	20 mm.	26-12 mm.	14 mm.	18-8.50 mm.	9.50 mm.
teres	38.50-19 mm.	19.50 mm.	20-10 mm.	10 mm.	15-8.50 mm.	6.50 mm.
tesellata	35-16.90 mm.	18.10 mm.	24-11.80 mm.	12.20 mm.	19.10-9 mm.	10.10 mm.
semiplota	26.10-8.90 mm.	17.20 mm.	17.50-5.10 mm.	12.40 mm.	13-4 mm.	9 mm.
moneta	34-17.50 mm.	16.50 mm.	21-12.50 mm.	8.50 mm.	15-8 mm.	7 mm.
gaskoini	30-14 mm.	16 mm.	18-8 mm.	10 mm.	15-6 mm.	9 mm.
rashleighana	29.90-14 mm.	15.90 mm.	18.90-16 mm.	2.90 mm.	14-12 mm.	2 mm.
erosa	45-30 mm.	15 mm.	30-20 mm.	10 mm.	20-13 mm.	7 mm.
vitellus	62.50-50.20 mm.	12.30 mm.	40-31 mm.	9 mm.	33-25.60 mm.	7.40 mm.
ostergaardi	20-14 mm.	6 mm.				
cicercula	18.50-11.90 mm.	6.60 mm.	11.50-7.10 mm.	4.40 mm.	10.30-6.50 mm.	3.80 mm.
poraria	22-15.50 mm.	6.50 mm.	15-9 mm.	6 mm.	11-8 mm.	3 mm.
fimbriata	13.50-9.10 mm.	4.40 mm.	7-5 mm.	2 mm.	6.10-4 mm.	2.10 mm.

RECORD OF SPECIES

Cypraea arenosa Gray.

Four orange-brown bands extend over dorsum of shell; sides are like those of *C. carneola* Linnaeus. Base, teeth, and interstices are white. Teeth are generally confined to aperture. Individuals are oblong or ovate in outline. Canals are but slightly produced.

This species appears to be the progenitor of two of the endemic Hawaiian cowries, *C. sulcidentata* Gray and *C. tesellata* Swainson. The relationship between these three forms is shown in certain similarities of immature shells, in certain aberrant adults, and in specific adult characters (4, 9).

I have not had the opportunity to measure the authentic collection of this species in Hawaii, but collections are recorded from the following localities: four from Honolulu Harbor dredgings; three in the L. A. Thurston collection in Bishop Museum, one of which was collected at North Kona, Hawaii, and two of which were taken between Mala wharf and Puunoa Point, Lahaina, Maui; and six in the collection of Ditlev Thaanum, four of which are from Lahaina, Maui, and two from about 20 fathoms of water at Waikiki, Oahu. Mr. T. T. Dranga collected three individuals from Lahaina, Maui, one at Fort Kamehameha, Oahu, and one specimen at Waikiki, Oahu.

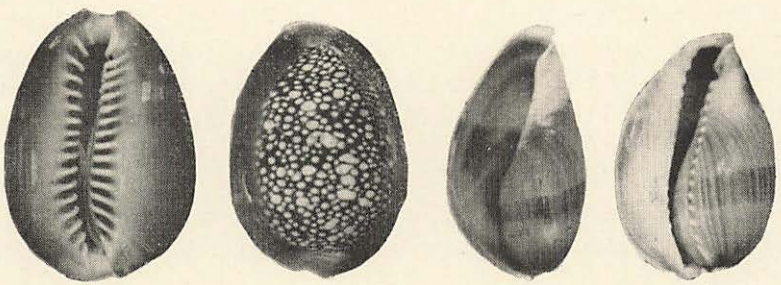


FIGURE 1.—*Cypraea caputserpentis:* a, ventral view; b, dorsal view; c, bulla; d, young shell.

Cypraea caputserpentis Linnaeus (fig. 1, *a-d*).

A reticulated brown pattern is well-developed over dorsum, showing irregular white blotches. A mantle line may or may not be present on dorsum. Sides are a deep brown which extends over lateral margins of base and gradually fades toward aperture to a light brown. Teeth are white and interstices are brown.

Young shells are grayish over dorsum; occasionally dorsum is light brown. A single wide brown band runs over dorsum. Margins are light brown with

scattered darker brown spots. Teeth, when they start to form, lack the brown interstices. Base is often of a fairly uniform light brown.

C. caputserpentis is the only cowry in the Hawaiian Islands that is really common in the living state. It is principally a shallow-water reef form, and may be taken from the under surfaces of dead coral heads and lava rock at low tides. The shell has excellent protective coloring, the reticulated surface of brown with white blotches blending with the algae-coral or lava-rock associations in which this species is found.

A number of individuals collected at Moku o Loe Island in Kaneohe Bay, Oahu have a smoky-white color over the dorsum, often almost entirely obscuring the typically reticulated brown pattern. This is the only locality in the Hawaiian Islands where such shells are found. The color distortion may be hereditary or may be due to some physiological upset in the development of the younger stages of the shell. The light coloring of these shells is definitely not due to a fungus which often attacks the substance of cowry shells.

Specimens of *C. caputserpentis* from different localities about Oahu and Kauai were measured for range in size. All measurements in this and following species are listed in order of length, width, and height. Oahu: three specimens from Black Point range from 33-23-15.50 to 26-17-13 mm.; four from Kailua Beach from 28-20.50-13.70 to 22-15-11 mm.; three from Fort Armstrong, from 37-24-18 to 29-19-14 mm.; 12 from Diamond Head, from 33-24-16 to 19-15-9.70 mm.; six from Koko Head, 29.50-22-15.50 to 25.50-20-13.50 mm.; 15 from Mokapu, from 30.10-22-14 to 20.80-14-10 mm.; 14 from Hanauma Bay, from 35-26-17.20 to 22-18-11 mm.; 17 from Rabbit [Manana] Island, from 31-22-16 to 24-16-10 mm.; 25 from Moku o Loe Island, in Kaneohe Bay, from 36-24-18 to 24-17-12 mm.; 19 from Kalama, from 30-20-15 to 17-12-8.50 mm. Kauai: three specimens, from 27-18-14 to 25.50-18-13 mm.

Cypraea carneola Linnaeus (fig. 2, *a*).

Four pinkish-orange bands over dorsum disappear at margins, which are fawn-colored. Teeth and interstices are a brilliant purple.

Some of the largest individuals of *C. carneola,* 88 to 62 mm. in length, to be found within its distributional range in the Pacific, occur at Lahaina, Maui, where they have been collected more abundantly than in any other locality in the Hawaiian Archipelago. Specimens from Lahaina often have greenish blotches on their dorsum beneath

the enamel sheen. These blotches probably represent fungus growths. I have observed the giant individuals copulating with smaller ones and living in the same environment. On Rabbit Island, off the shore of Oahu, I collected the smallest mature Hawaiian individual that I have seen; it measures 30.50 mm. in length. Another small specimen 32 mm. in length in my collection was taken in the vicinity of Makena, Maui.

Concerning *C. carneola*, Ostergaard (9) states, "The species . . . is conspicuous for its frequency as a fossil in the limestone of Honolulu harbor as well as for its consistent small size. The living forms are rare in Hawaii, but are large."

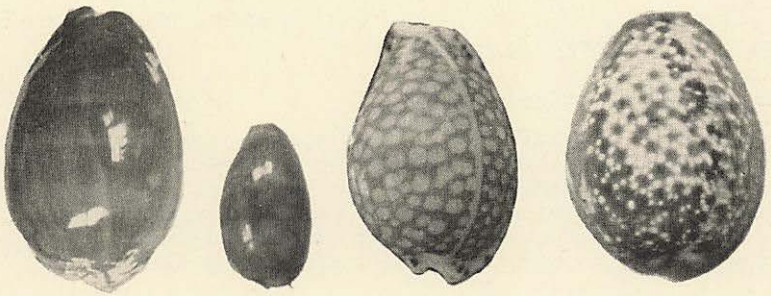


FIGURE 2.—a, *Cypraea carneola;* b, *C. fimbriata;* c, *C. gaskoini;* d, *C. helvola.*

C. carneola ranges in size as follows: Maui: four specimens of *C. carneola* from Lahaina range from 88-50.50-43.25 to 56.40-32.60-27.70 mm.; one from Makena, 32-20.60-17 mm. Oahu: one from Sand Island, Honolulu Harbor, 54-32-26.60 mm.; one from Rabbit Island, 30.50-19.75-17.50 mm.

Cypraea cruenta Gmelin.

A poorly formed, reticulated, brownish color pattern rests on dorsum. Purple spots mark the margins of dorsum. Sides and base are white with purple spots; teeth are milky white and interstices are orange.

I have seen seven specimens from Honolulu Harbor dredgings and two beach shells from the shores of Cocoanut Island, Hilo Bay, Hawaii. I had no opportunity to measure specimens.

Cypraea erosa Linnaeus.

The most obvious characters which separate this species from others are the greatly produced columellar margin which is roughened into crenulations by

having the columellar teeth extend from aperture over sides of shell and the two squarish brown blotches placed in the middle of shell where dorsum joins margin.

This is one of the rarest of the Hawaiian cowries. I have seen only one authentic record of a living specimen, taken on Kauai. It is not uncommon as a fossil in certain areas about Oahu. Ostergaard (9) has reported it from the following localities: Hahaione Valley, Wailupe Point, Honolulu Harbor, King and Richards Streets in Honolulu, Kupikipikio, and Nanakuli. The species apparently borders on extinction.

I have in my collection two specimens dredged from Honolulu Harbor.

Specimens of *C. erosa* dredged from Honolulu Harbor range in size from 45-30-20 to 30-20-13 mm.

Cypraea fimbriata Gmelin (fig. 2, *b*).

Dorsum is faint purple with scattered brownish-purple dots. Canals are margined dorsally and ventrally with brilliant purple. Base, teeth, and interstices are white. A discontinuous, relatively broad brown band circles dorsum and extends over left margin onto base of shell where it disappears at aperture.

A bulla is colored purple over dorsum, margins, and interior. Extremities are white. Bullae are obscurely one- or three-banded over dorsum.

Beach shells may often be faded to white; the brown spots normally on the dorsum of such shells are often lacking. Occasionally beach shells are extremely dark purple over the dorsum.

C. fimbriata ranges in size as follows: Oahu: two specimens from Waikiki Reef, from 11-6.50-5 mm. to 11-6-5 mm. Kauai: three specimens, from 13-7-5.80 to 12-6.80-5.20 mm. Pearl and Hermes Reef, 19 specimens, from 14-7-6.10 to 9.50-5.20-4.20 mm.; Seal Island, 12 specimens, from 12-7-5.80 to 9.10-5-4 mm.

Cypraea gaskoini Reeve (fig. 2, *c*).

Shell has a dorsal reticulated color pattern of light brown, allowing numerous, relatively large milky-white spots to show. White margins are punctuated with distinct chocolate-brown spots. A well-defined umbilicus is present over posterior canal. Base is pure white except on outer one-fourth of columellar side, where it is splashed with distinct chocolate-brown spots identical to those on shell margins. Teeth and interstices are white. A well-defined white mantle line is on dorsal surface.

C. gaskoini has two shell forms. The most common one is elongate-oval with a low dorsum in proportion to the length of the shell, whereas the other is rotundly ovate, with a high dorsum in relation to the shell length. In elongate-ovate individuals the shell is asymmetrical trans-

versely, the shell bulging toward the left side. This condition is in sharp contrast to species having a fairly well-defined symmetrical shell (i.e., *C. mauritiana*). Rotund individuals have symmetrical shells. Individuals are to be taken from the center of coral heads where they may be found secreted at the base of coral branches and in holes in the coral head. Individuals are most often collected at the entrances to Honolulu and Pearl Harbors; on "Rat" [Popoia] Island; on Waikiki Reef, Oahu; and at Hilo, Hawaii.

Fifteen specimens of *C. gaskoini,* from the mouth of Honolulu Harbor, range in size from 30-18-15 to 14-8-6 mm.

Cypraea helvola Linnaeus (fig. 2, *d*).

This species exhibits a great deal of variation in color, the dorsum varying from a groundwork of greenish, orange brown, to brown. Brown spots on dorsum are larger than white and are fewer in number. Dorsal surface of canals is colored with pale to brilliant purple. Margins, where they unite with dorsum, are punctuated with slight depressions, especially on outer lip margin of shell. Margins vary in color from orange brown to orange purple to an occasional white. Columella is white. Base color varies from orange brown to flesh; teeth colored like base. A mantle line is typically present on dorsum although it may occasionally be lacking.

Bullae are purplish brown and are obscurely three-banded over dorsum. Anterior area of columella is white. Spire whorls with the exception of the brown nuclear whorl are white. The first adult coloring to appear in immature shells is orange brown added faintly on base below columella teeth. Teeth in immature shells are white. Columella teeth develop before outer lip teeth. Mantle line on dorsum appears to be more prominent on newly formed mature shells than on older ones, which become typically quite heavier by additions of shell material to dorsum and to lateral margins of the shell.

The largest individual yet recorded from the Hawaiian Islands is 31.10 mm. long by 21.25 mm. broad by 15.50 mm. high and was taken on Midway Island. The species in the living state is quite rare generally, but at specific localities it may be taken in abundance. Fort Kamehameha, Oahu is an especially favorable collecting ground. At low tide where the surf is generally heavy, individuals have been collected from beneath coral rocks where they had secreted themselves in holes.

C. helvola fades greatly in collections. I have shells, taken seven years ago on Oahu, which have now faded to a general yellow-orange color, with the brilliant purple on the extremities likewise fading to a dull purple. When these shells were first collected they were of a dark orange brown with the extremities brilliant purple. Roberts (11) states concerning Hawaiian *C. helvola,* "Those shells from the Sand-

wich Islands are often pale yellow, faintly spotted, with a whitish base and extremities." This description applies only to the faded dead shells which were dredged in vast quantities from the area of Honolulu Harbor, Oahu, and to those which have been exposed to the sun's rays on the beaches for a long time.

C. helvola ranges in size as follows: Oahu: 53 specimens from Fort Kamehameha, from 23-14-11 to 9-10-7 mm.; seven from Black Point, from 24-16-12 to 19-14-10 mm.; one from Nanakuli, 23-17-11 mm. Midway Island: one specimen 31-21.50-15 mm. Pearl and Hermes Reef, 26 specimens from Grass Island, from 30-20-13.50 to 15-10-8 mm.

Cypraea isabella Linnaeus.

Orange-fawn-colored dorsum is covered with brown or blackish-brown dots, dashes, and flecks. Canals have brown or blackish-brown blotches superimposed over orange on dorsal surface of canals; this condition is present in all living specimens authentically collected in Hawaii. Sides are white, as are base, teeth, and interstices. Dorsum is obscurely three-banded by light-brownish bands.

In bullae the black and brownish-black flecks on dorsum extend into and around columella of shell. The orange spot is first formed over posterior canal, and is laid down independently of the black color which is finally formed over it.

Shells from Sand Island at the entrance to Honolulu Harbor are often bleached to a yellowish orange; such shells are common in many museum collections. The large and small individuals have been collected together from beneath the same piece of coral rock or in holes in reefs on Waikiki reef, Oahu; Midway Island; and Pearl and Hermes Reef. The size difference in individuals of this species represents merely individual variations in size, and in no way is subspecific. Beach shells often have a clear brown-colored dorsum, for the dots and dashes are readily eroded away by the rolling of shells on the beach.

In specimens in my collection, the black blotches which are superimposed over the orange coloring on the dorsal surface of the canals are laid down as the immature shell is about to reach maturity. The teeth in this species seem to form rather late in shell development; certain specimens in my collection indicate that fully developed teeth are among the last of the mature characters acquired.

C. isabella ranges in size as follows: Kauai: three specimens from 29-15-12 to 15-8-6 mm. Oahu: seven from Waikiki reef, from 34-19.50-16 to 20-11-8 mm.; Honolulu Harbor, six specimens from Sand Island, from 37-19-15 to 21-11-8.50 mm.; one from Kaneohe Bay,

43.50-24-20.50 mm.; four from Pearl Harbor dredgings, from 37-21-17.50 to 27.50-15-12 mm.; one from Nanakuli, 24-12-9 mm.; one from Koko Head, 21-11-8.50 mm.; one from Waimanalo, 17.50-9-7 mm. Maui: five specimens from Lahaina, from 30.50-14.50-12 to 26-14-11 mm.; two from Mala, from 29-15-12 to 24.50-13-11 mm. Midway Island, nine specimens from 32-16-13 to 15-8-6 mm. Pearl and Hermes Reef, 18 specimens from Seal Island, from 40-21-17 to 16-7.50-6 mm.

Cypraea lynx Linnaeus.

Dorsum is spotted with brown or blackish brown. Mantle line on dorsum is well-defined. Base on columella side is perfectly flat. Interstices between white teeth are brilliant orange.

This species is extremely rare in Hawaii. I know of five collections of living specimens all made on Oahu. I have seen one specimen from Waikiki reef, and four from Moku o Loe Island, Kaneohe Bay; three of these were taken on the flat on the west side of the island and one from the north end. I have had opportunity to measure only one of these specimens; it measures 38 by 23.75 by 20 mm. Dredged specimens may be found on Sand Island, Honolulu Harbor, Oahu.

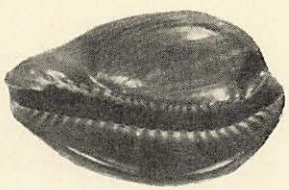


FIGURE 3.—*Cypraea mauritiana*, subadult, ventral view.

Cypraea mauritiana Linnaeus (fig. 3).

This is the second largest of the Hawaiian cowries, being next in size to *C. tigris* Linnaeus. A well-defined reticulated brown pattern is present over the back. Shell margins are covered with a thick, deep brown band which extends continuously over entire base. Teeth and interstices of outer lip teeth are brown, whereas those of columellar lip teeth are whitish.

Immature individuals (both bullae and immatures with outer lip just beginning to form) have four transverse brown bands running over dorsum. These are often entirely obscured in mature individuals by later superposition of reticulated dorsal color pattern over them in the adult. The bands are broken from time to time by light cream-colored triangles. Spaces between brown bands are filled with solid light cream brown or with cream-brown triangles. Spire is very sharp and small and is one of the last immature characteristics to be obscured by later additions of calcium to shell. Base of an immature shell is light cream

brown, instead of the dark chocolate brown of a mature shell. Shell sides are likewise cream brown. Interior of immature shells is brilliant purple, this color being sometimes completely obscured in mature shells by the addition of white, or at least subdued to dull purple.

I have usually collected individuals from lava rock exposed to a rather heavy surf. A notable collection of immature specimens in the bulla stage was made from a pool in a lava ledge about 15 feet above the breaking surf at high tide in the vicinity of Hanauma Bay, Oahu. This pool was splashed with sea water only when the surf was heavy at high tide. Other specimens have been taken from the base of Diamond Head, Black Point, Waikiki, and Rabbit Island, Oahu; Kona, Hawaii; Wailua River and Kipukai, Kauai.

The color pattern on the dorsum of Hawaiian *C. mauritiana* in recently mature individuals is punctuated with fairly circular spots. These appear to become obscured by the addition of brown in old adults as the shell is thickened. One old adult specimen from Rabbit Island has a completely reddish-brown dorsum with all but a few of the dorsal spots absent.

In my experience in field collecting, individuals found together were generally either uniformly large or small. Extreme sizes from the largest to the smallest (see measurements) were not found together living under similar ecological conditions. A series of four shells collected from Kona, Hawaii measures 60, 59.40, 59, and 56.5 mm. in length, whereas a collection of four from the vicinity of Wailua River, Kauai, on rocks near Lydgate Park measures 86, 84.60, 84, and 83.30 mm. in length. Another series of five uniformly large individuals from Kipukai, Kauai measures 95, 90, 89.10, 86.25, and 86 mm. in length.

Specimens in my collection range in length from 96 to 48 mm., the smallest specimen approaching dwarfism. T. T. Dranga had an even smaller specimen in his collection from Hawaii.

C. mauritiana ranges in size as follows: Kauai: one specimen, 55-35.50-26 mm.; four from Wailua River, from 86-55-44.15 to 83.30-55.20-43 mm.; Kipukai, five from one area, from 95-63.10-41.80 to 86-61-45 mm., three from another area, from 92-60.20-43 to 74-55-38 mm. Oahu: one from Waikiki, 48-31.50-22.60 mm.; one from Makaha Beach, 92-60.20-49 mm.; one from Rabbit Island, 80-55.10-41 mm. Hawaii: four from Kona, from 60-45-28.70 to 56.50-40.60-26 mm.; three from Kiholo, from 96-69.50-49 to 91.50-70-47 mm.

Cypraea moneta Linnaeus.

Shells are greenish yellow to yellow orange on dorsal surface and margins; occasionally margins are white. Base, teeth, and interstices are milky white. Center of dorsum is raised and a shallow groove between it and margins sets dorsum off from margins as a raised hump.

Individuals from Moku o Loe Island in Kaneohe Bay are large compared with those from other Hawaiian localities. Some of the individuals from this locality are a deep orange yellow which may grade into yellow green. Of two shell forms from Moku o Loe, one has two short tubercles on the posterior-lateral regions of the shell, the other is without tubercles. Moku o Loe is the only locality in the Hawaiian Islands where the majority of *C. moneta* are bright orange yellow. The individuals from Moku o Loe were collected from seaweed about 50 to 100 feet from shore, in three to five feet of water. The bay water is calm in this area and covers a partially dead coral reef shelving out from the island. At Waikiki reef, near the Aquarium, living specimens have been collected under coral rocks five feet from shore.

This extremely common Indo-Pacific species is rare in the Hawaiian Islands in both the living state and as a beach shell.

C. moneta ranges in size as follows: Oahu, 24 specimens from Moku o Loe Island, from 34-20-15 to 23-15-11 mm.; 22 from Heeia Kea, Kaneohe Bay, from 27-18-13 to 17.50-13-8 mm.

Cypraea ostergaardi Dall (fig. 4, *a*, *b*).

Shell is whitish to cream to light brown and is abundantly ornamented with chestnut-brown spots evenly sprinkled over the dorsal surface. Base, aperture, and teeth are white. Lateral margins of shell are elevated and pitted. The small, delicately cut teeth are not confined to aperture but extend over a narrow zone of base.

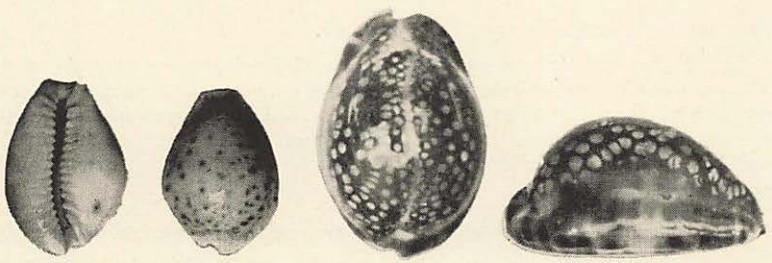


FIGURE 4.—**a**, **b**, *Cypraea ostergaardi: a*, ventral view; *b*, dorsal view. **c**, **d**, *C. reticulata: c*, dorsal view; *d*, lateral view.

This species is the rarest of the endemic cowries, and I believe that no live individuals have been taken. Collections of beach shells have been made from the Honolulu Harbor dredgings, and from Pearl and Hermes Reef. Spicer (14) reports this species from Midway Island. The shell is related to *C. helvola* Linnaeus, a species from which it probably evolved, but is quite distinct. I have not had opportunity to make complete measurements of the individuals which I have seen but specimens that I have observed range in length from 14 to 20 mm.

Cypraea poraria Linnaeus.

Shell is purple tinged with brown. Circular brown dots with white centers are on dorsum. Sides and base are purple; teeth at aperture are white.

This species is extremely rare in the living state. It is not uncommon as a beach shell in Hawaii, but has not been reported as fossil. The one live collection that I have seen was taken from within the branches of a live coral head in several feet of water on Waikiki reef where the surf is of moderate intensity.

Six specimens of *C. poraria* from Sand Island in Honolulu Harbor range in size from 22-15-11 to 15.50-9.50-8 mm.

Cypraea rashleighana Melvill.

The coloring is like that of *C. teres* Gmelin, an apparently closely related species. Unlike *C. teres,* however, the shell is always broader in proportion to length, margins are fairly equal, and the shell in dorsal view is fairly bilaterally symmetrical.

Shells are not infrequently found in the Honolulu Harbor dredgings. I do not know of an authentic living Hawaiian collection.

Three specimens of *C. rashleighana* dredged from Honolulu Harbor range in size from 29.90-18.90-14 to 14-16-12 mm.

Cypraea reticulata Martyn (fig. 4, *c, d*).

A reticulated color pattern of brown is well-developed over dorsum. Sides are brownish with smoky-blue tinges; over this color are well-defined brown or brownish-black spots. A large brownish-black blotch is on columellar side of base near aperture at the point of maximum basal width. Teeth as they extend over base are brown; columellar teeth become white as they extend on to columella.

Individuals of this species show scarcely any variation in color pattern. One specimen in my collection from Kauai is almost entirely chalky white over the dorsum and lateral margins of the shell. This abnormal coloration appears to have been caused by a fungus growth.

The only normal coloration on the shell is the brown-colored teeth and the characteristic brown blotch on the basal columellar surface.

In the Hawaiian Islands, living specimens of *C. reticulata* may be most commonly found at Lahaina, Maui. When specimens are taken alive, they are usually found under broken lava and coral rock. I have always taken individuals where the surf was fairly heavy.

I was told by certain Japanese that on Kauai they ate these mollusks, which were boiled, broken open, and put into soups.

C. reticulata ranges in size as follows: Oahu: two specimens from Black Point, from 68-46.70-35.20 to 65-45.10-34 mm.; one from Waikiki, 65-41-33 mm.; one from Rabbit Island, 54-38.27-50 mm.; one from Diamond Head, 49-33-24 mm.; one from Hanauma Bay, 64-43-31.70 mm.; two from Mokapu Point, from 63.50-41-31 to 62-41-30.50 mm. Kauai: six specimens from 64-40.50-32.20 to 54-35.40-27.30 mm. Maui: 19 specimens from Lahaina, from 67.90-44-33.10 to 46-33.50-24.25 mm.

Cypraea semiplota Mighels (fig. 5, *a, b*).

Dorsum is blackish brown to brown and is sprinkled with numerous small white spots. Extremities are light brown turning orange. Margins are pitted. Base is white and teeth and interstices are brown.

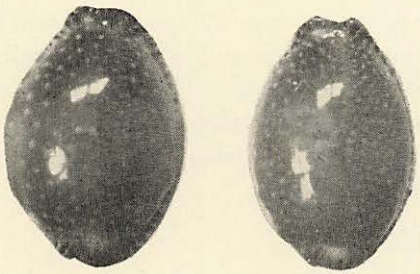


FIGURE 5.—*Cypraea semiplota:* **a,** broad body form; **b,** more elongate body form.

Shells from the Honolulu Harbor dredgings are often bleached orange to orange brown to yellow orange. The spots on the dorsum may be lacking. Schilder (12) states that a shell 19 mm. long from Laysan Island is a giant; 11 specimens reported here are larger, ranging in length from 20.70 to 26.10 mm.

The individual variants, *C. polita* Roberts and *C. annae* Roberts, are truly size variants, for individuals of varying sizes and shapes have commonly been collected in the same environment at Waikiki, Oahu and elsewhere in the Hawaiian Islands (Ingram 3). Measurements show that when they are considered as a whole there is a gradual variation from one individual to the next.

This species is the most common of the Hawaiian endemic cowries, being especially abundant on many of the islands as a beach shell.

C. semiplota ranges in size as follows: Oahu: 17 specimens from Waikiki reef, from 26.10-17-13 to 9.80-6.20-5 mm.; four from Black Point, from 16.20-10-8 to 13.60-8-6.30 mm.; 11 from Honolulu Harbor, Sand Island, from 24.90-14-11.50 to 10-6-4.80 mm. Kauai: seven from 13-8.50-6.50 to 8.90-5.50-4 mm. Pearl and Hermes Reef: nine from 15-9-7 to 11.40-7-5.50 mm.; Southeast Island, 13 specimens from 21.50-12.10-10.20 to 12-7-5.50 mm. Midway Island, eight specimens from 20.80-17.50-9.90 to 12.20-7-6.30 mm.

Cypraea scurra Chemnitz.

Shell is quite cylindrical. Mantle line is prominent on dorsum, and reticulated pattern of brown forms large irregular circular spots. Laterally, sides of canals are tinged with brown. Margins are light brown marked with dark brown spots. Teeth are fine and are brown; interstices are of a much lighter brown. Columella is white.

I have seen only one authentic living collection of this species from the Hawaiian Islands, taken near Fort Kamehameha, Oahu. I have collected two beach shells at Paumalu, Oahu and have seen 10 individuals from the dredgings of Honolulu Harbor.

Two specimens of *C. scurra* from Paumalu, Oahu measured 51.50-31-19 mm. and 38.90-20-17 mm.

Cypraea sulcidentata Gray.

Dorsal surface is banded by four pinkish-brown bands. General shell color is creamy brown. Dorsum is greatly humped in relation to shell length. Sides are banded by creamy brown. Teeth of both lips extend a short distance over base, those on outer lip extending farther on base than those on columellar lip. Teeth are deeply incised; more so than are those of any other Hawaiian cowry. Columellar teeth extend on to columella as narrow straight ridges. Teeth and incisors are ivory white.

Immature shells have an extremely minute spire. Teeth are formed in aperture as raised white lines before they begin to form and become deeply incised on columellar and outer lips. The four color bands present only on the dorsum of a mature shell extend over sides and onto base of an immature one.

This endemic cowry is rarely taken alive but is not uncommon in certain areas as a beach shell. Shells from the Honolulu Harbor dredgings are bleached to a brilliant orange and resemble in color the orange cowry, *C. aurantium* Gmelin. In bleached shells, the dorsal bands are usually obscured and are often wanting. Individuals are more commonly taken alive at Pearl and Hermes Reef than anywhere else in the Hawaiian Archipelago. The specimen 69 mm. long from Sand Island, and the one 60.50 mm. long from Oahu represent gigantism in the species.

C. sulcidentata ranges in size as follows: Oahu: one specimen from Paumalu, 38-28-23 mm.; six from Sand Island, Honolulu Harbor, from 69-39-39 to 29.40-19-16 mm.; no specific locality, three specimens from 60.50-40-32.25 to 39.10-38.40-24 mm.; Rabbit Island, three specimens from 37.10-26.10-22.25 to 28.90-21-16.70 mm.; Pearl and Hermes Reef: two specimens, 41.90-30.20-23.80 to 34-24.70-19.65 mm.; five specimens from Southeast Island, from 38.25-28.20-21.90 to 28.15-22.10-17.15 mm.; two from Seal Island, 35.50-24-20.50 to 32.80-24.80-18.50 mm.

Cypraea talpa Linnaeus.

Four brown bands separated by three whitish-brown bands extend over dorsum. Margins, base, and teeth are deep chocolate brown and interstices are lighter brown.

Collecting reveals that Lahaina, Maui provides the most productive collecting grounds for living individuals, which are rare. The 44 mm.-long specimen listed is extremely small for this species.

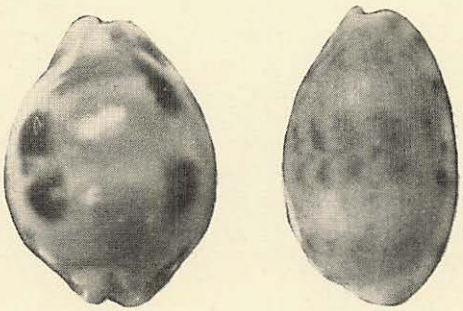
C. talpa ranges in size as follows: Oahu, Pearl Harbor channel, two specimens, 68-36.50-30.20 to 44-24-20 mm. Maui: Lahaina, one specimen 53-26.50-22.50 mm.

Cypraea tesellata Swainson (fig. 6, *a*).

Dorsum is indistinctly three-banded with darker orange brown or brown than exists between these bands. A pair of square, dark brown blotches are on either side of dorsum as it curves to meet margins. Anterior and posterior canals are much produced. Sides are whitish, broken with irregular orange-brown blotches. Margins of base are upturned toward shell margins forming a ridge around sides of shell. Base is blotched with white and orange brown. Teeth are orange brown and interstices are whitish. Teeth are fine.

Immature shells are three-banded with light brown separated by two white bands over the dorsum. Dorsal color bands extend over the sides and onto base, running to aperture of shell. Until individuals are well on toward maturity they lack the two pairs of square color spots on sides of dorsum. Teeth are brown and interstices are white at an early age.

Next to *C. ostergaardi* Dall, *C. tesellata* is the rarest of the endemic forms, both in the living state and as a beach shell. The only authentic living collections of this species that I know of were made by W. G. and Alec Anderson at Pearl and Hermes Reef, and by Ditlev Thaanum at Hilo, Hawaii. I have almost perfectly preserved specimens from the beach at Paumalu, Oahu. Shells from Sand Island, Honolulu Harbor are often bleached to yellow and white, and do not show the true coloring of the shell. These latter specimens have worked their way into the collections of the world.



a b

FIGURE 6.—**a**, *Cypraea tesellata;* **b**, *C. teres.*

C. tesellata ranges in size as follows: Oahu: 10 specimens from Paumalu, from 35-24.50-19 to 28.80-21.25-17 mm.; seven from Sand Island, Honolulu Harbor, from 35-24-10.10 to 16.90-11.80-9.10 mm.

Cypraea teres Gmelin (fig. 6, *b*).

Right margin is much more prominent than left. Dorsal ground color varies from green to blue, with irregular brown or brownish-green flecks and with blotches of varying size. Dorsum has a large irregular brown blotch in the very center. White margins of shell are spotted with brown or with brownish-black. Base, teeth, and interstices are milky white. Shell is umbilicate. The ground color of eroded beach shells is brilliant purple. Dredged material from Pearl and Honolulu Harbors is faded to milky white with the brown color markings faded but still present.

Immature shells are faintly three-banded by indistinct broken lines running transversely across the longitudinal axis of the shell; these lines are carried around the shell margin to the columellar side of the base and extend to the very aperture of the shell. The brown or blackish-brown spots on the columellar side of the shell are not added until fairly late in shell development.

I have collected specimens under coral rock in shallow water below low-tide mark on Waikiki reef, in front of the marine laboratory of

the University of Hawaii where the surf is relatively mild. I have also collected specimens at Paumalu, Oahu from holes in the reef where a heavy surf was generally present.

C. teres ranges in size as follows: Oahu: two specimens, 23-12-10 to 22-12-10 mm.; eight specimens from Sand Island, Honolulu Harbor, from 38.50-19.25-15 to 19-10-8.50 mm.; two from Paumalu, 28-15-11.50 to 27-14-11 mm.; one from Waikiki reef, 29-16-13 mm.

Cypraea tigris Linnaeus.

Shell is very bulbous. Brown or blackish-brown spots on the dorsum are quite prominent. The base, teeth, and interstices are ivory white.

C. tigris is the largest of the Hawaiian cowries. I have seen two authentic records of this species from the Hawaiian Islands; one collection is from the reef at Lahaina, Maui and the other from Waikiki reef in the vicinity of the marine laboratory of the University of Hawaii.

Harris (2) published a valuable paper on the occurrence of *C. tigris* Linnaeus in the Hawaiian Islands. He includes two records from Lanikai, Oahu from two fathoms of water at the outer side of the reef, and one specimen from Hauula, Oahu in six feet of water. Five records of *C. tigris* from the Bryan collection in Bishop Museum are also included from Hawaii: one from Waikiki and one from Honolulu Harbor; one from Niihau or Kauai; one from Niihau; and one from "Hoopuloa, Island of Hawaii." I am inclined to discredit these records, in the light of mislabeled locality data in the Bryan collection (7, 8).

The size variation in *C. tigris* is based on figures quoted in Harris (2), based on the inch. Height measurements are not included in this paper.

Oahu: one specimen from Lanikai, 117-77 mm.; one from Hauula, 147-92 mm.

Cypraea vitellus Linnaeus.

Back is brown with numerous, relatively large, white spots on dorsum and margins. Margins are banded with numerous, fine, vertical bands of alternating brown and white. Base, interstices, and teeth are white. One specimen from Moku o Loe Island is grayish brown over the dorsum and sides; the common color of the dorsum and lateral margins is brown.

Individuals of this species that I have examined have been uniformly large for the species. Collecting areas in the Hawaiian Islands

where individuals are most commonly taken alive are at Lahaina, Maui; the entrance to Honolulu Harbor; and Moku o Loe Island, Oahu. The species, both as living and as a beach shell, is rare.

C. vitellus ranges in size as follows: Oahu: two specimens 58-34-27 to 53-33-27.50 mm.; one from Sand Island, Honolulu Harbor, 62.50-40-33 mm.; one from Moku o Loe Island, 50.20-31-25.60 mm.

"Pustularia" cicercula tricornis Jousseaume.

Shell is bulbous with the canals produced. The entire shell is light orange brown. Dorsum is marked by small pustules with brown over them. Teeth and interstices, for their length over base, are orange; teeth and interstices in aperture are white on columellar side. Beach shells are often eroded entirely white.

Ten specimens of *"Pustularia" cicercula tricornis* from Fort Armstrong, Oahu range in size from 19-11-10.10 to 11.90-7.10-6.50 mm.

"Pustularia" annulata (Gray).

Dorsum is smooth, round, and marked by scattered circular yellowish spots rimmed in light brown on a white background. Base, teeth, and interstices are white. Teeth are minute and are confined to aperture.

I have collected beach shells from the Honolulu Harbor dredgings and from Fort Armstrong, Oahu, but have not seen a live collection from the Hawaiian Islands.

"Ipsa" childreni (Gray).

Dorsum is ridged by brownish raised lines; these extend over margins and base and are continuous with teeth in aperture. There is a raised line of demarcation between sides and dorsum. Entire shell is brownish with ridges a darker brown; interstices are white.

I have seen two beach shells from the Honolulu Harbor dredgings. To the best of my knowledge no living specimen has been collected.

Nuclearia madagascariensis Gmelin (fig. 7, *a, b*).

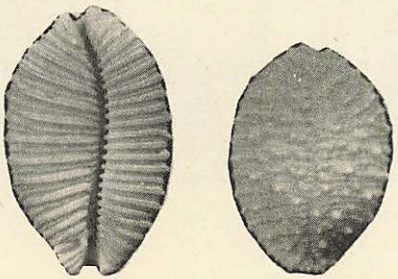
Dorsal surface is covered by prominent raised tubercles which are connected by numerous raised ridges. Sharp ridges extend from basal area over sides of shell to dorsal surface. Teeth have white centers margined with brown. Beach shells are pure white, whereas freshly collected shells are tinged with pinkish brown.

Young specimens with both lips indicate that transverse ridges connecting tubercles or pustules on back are added fairly late in development. Formation of teeth extending across shell base to lateral shell margins and addition of color to base comes only with shell maturity.

Of two shell forms of this species, one is noticeably oval and the other is elongate. The oval form is more common; of 66 measured

specimens, only seven were cylindrical. Mature shells from a given locality show a great size range, from 42 to 19 mm. in length.

Living specimens are extremely rare. Living collections known to me have been made at Hilo, Hawaii; Waikiki reef, Kaneohe Bay, and Black Point, Oahu; Midway Island; and Pearl and Hermes Reef. Beach shells are common at a few areas on Oahu and Kauai. On Oahu, beach shells are abundant at Fort Armstrong, at Sand Island, and at Paumalu; and they have been taken in abundance in certain areas on Pearl and Hermes Reef. This is one of the five endemic species; it seems likely that it is descended from *N. nucleus* (Linnaeus) (Ingram 5).



a b

FIGURE 7.—*Nuclearia madagascariensis:* a, ventral view; b, dorsal view.

N. madagascariensis ranges in size as follows: Oahu: 15 specimens from Fort Armstrong, from 42-25-18 to 22-15-11 mm.; mouth of Pearl Harbor, three from 35-22-15 to 32-21-14 mm.; two from Sand Island, Honolulu Harbor, 32-22-14 to 31.50-23-14 mm.; 40 specimens from Paumalu, from 35-23-15 to 18-12.50-8 mm.

Nuclearia nucleus (Linnaeus).

The shell is considerably smaller than most *N. madagascariensis;* its width is always much less in proportion to length. Tubercles are much more numerous on dorsum and ridges are much reduced when compared with *N. madagascariensis.* Shell is ovate. Teeth extend over base and onto lateral margins of shell. Beach and dredged specimens are white or light brownish white.

Specimens measure 16 to 22 mm. in length. The species is rare in Hawaii, although a number have been collected in the dredgings from Honolulu Harbor.

USE OF COWRY SHELLS BY HAWAIIANS

Collections in Bishop Museum indicate that use of cowry shells by Hawaiians was not extensive. Of the 29 species of Cypraeidae re-

ported from Hawaii, only six seem to have been used by native Hawaiians for ornamentation, for food, and for "squid" lures (*makau lu he'e*).[2]

Cypraea moneta were strung on heavy cord or cloth for leis, and, in modern times, for hat bands. *Nuclearia madagascariensis* and *C. caputserpentis* were made into bracelets and anklets. *C. mauritiana* and *C. reticulata* were, and still are, used occasionally for food.

FIGURE 8.—Squid lure with bone hook.

Two cowries, *Cypraea mauritiana* and *C. carneola* were employed by Hawaiians in making lures for squid, which were used as food. *C. mauritiana* was more commonly used, probably because it is the more common of the two species. One or two cowries were attached

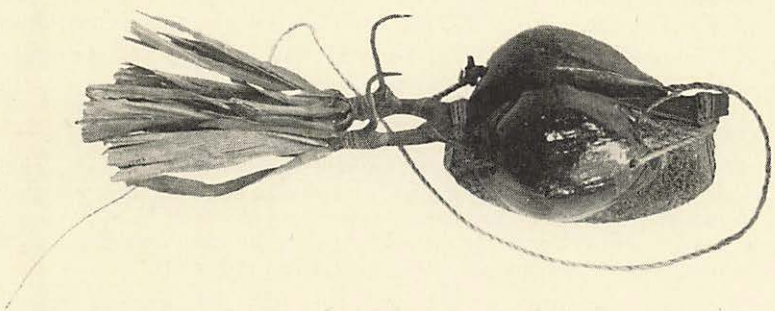


FIGURE 9.—Squid lure with iron double hook.

to a stone sinker shaped to resemble the general form of the cowry (figs. 8, 9). Between the shell and the rock, a twig bearing one or two

[2] The term squid is almost universally incorrectly employed for octopus among the Hawaiian population.

bone, later iron, hooks was affixed by means of thongs which were run through holes bored in either end of the shell and wrapped around the sinker. A bunch of leaves was bound around the end of the twig nearest the hook, and a lead line was attached for the fisherman to hold. The whirling lure attracted the squid, which wrapped its tentacles around the lure or was impaled on the hook.

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