Studies on Populations of the Cowrie *Erronea errones* (Linnaeus)

BY

FRANZ ALFRED SCHILDER

AND

MARIA SCHILDER

University of Halle, German Democratic Republic

(5 Maps; 6 Tables)

Erronea errones (Linnaeus, 1758) is a rather common cowrie species distributed throughout the Indo-Pacific Ocean from Ceylon to Samoa and from Japan to the Exmouth Gulf and Sydney (F. A. Schilder, 1965, p. 181). The individual variation in many characters of the shell is considerable; nevertheless the differences in the means or medians of different populations often can be demonstrated to be mathematically significant.

Recent examination of far more than 4000 specimens (cf. M. Schilder, 1967a, p. 373) has indicated that the geographical races defined 30 years ago (F. A. & M. Schilder, 1938, p. 152) can hardly be maintained as taxonomic units. However, our studies demonstrated the existence of an unspotted sympatric mutant living around Broome in Western Australia (F. A. Schilder, 1968a, 1968b).

In the present paper we intend to investigate the correlation between the medians of 5 selected characters in 133 natural populations coming from all regions of the inhabited Indo-Pacific Ocean, and the geographical distribution of these medians. These investigations quantitatively far exceed former studies on the same subject published 7 years ago (F. A. & M. Schilder, 1961), though localities from which we studied one or very few shells only have been completely disregarded.

CHARACTERS

The following 5 characters have been selected for this study, as their records are most complete in our card registry of all personally examined cowrie shells:

L = length of the shell in millimeters;
BL = maximum breadth in % of length, mostly indicating also the degree of callosity of the margins and of the base;
DB = dorsal central blotch;
AS = anterior terminal spots; usually the size of the right (labial) spot has been considered only, the few cases excepted in which the left (columellar) spot is larger than the right one;
BC = color of the base and the unspotted margins; the bluish grey zonate inner lip in rather young specimens has been disregarded.

According to previous papers (e. g. Schilder, Schilder & Houston, 1964, pp. 158-159, table 2) we have classified each character in 6 classes; Table 1 shows the meaning of the figures 1 to 6 in the following paragraphs.

The convexity of the base, the narrowness of the aperture, and the visibility of the dorsal zones (Schilder & Houston,

Table 1

Class	1	2	3	4	5	6
L	17-19	20-21	22-23	24-25	26-28	29-35
BL	53-54	55	56	57	58	59-61
DB	absent	obsolete	small	rather large	large	very large
AS	absent	obsolete	small	rather large	large	very large
BC	white	almost white	yellowish white	pale yellow	rich yellow	orange

1964, table 2) have been omitted because these characters have not been registered in many populations, especially several decades ago; in our earlier paper on *Erronea errones* we have considered the characters DB and AS only (F. A. & M. SCHILDER, 1961).

A dash (–) in a column indicates that the character has not been recorded in a sufficient way.

POPULATIONS

Table 2 contains the 133 populations considered for the present study, as they comprise a satisfactory number of adult specimens. The 8 columns indicate:

1. the designation of the region and area according to F. A. SCHILDER, 1965, pp. 174-175;
2. the locality; an asterisk (*) indicates populations comprising at least 40 adult specimens;
3. the collector, or if in parentheses, the collection or museum in which the population has been preserved; series collected by the same collector at the same place but at different times have been pooled to a single population;
4. median length (L) in millimeters;
5. median relative breadth (BL) in % of length;
6. median size of dorsal blotch (DB);
7. median size of the anterior spots (AS); and
8. median color of the base (BC), each expressed in classes 1 to 6 as explained in Table 1.

Table 2

			L	BL	DB	AS	BC
13m	Tuticorin	Winckworth	32	58	3	2	3
13c	Ceylon	Eulenburg	25	57	1	5	4
	Ceylon	(Steinfurth)	28	56	4	5	4
	Ceylon	Stoliczka	22	55	3	5	4
	Krusadai	Winckworth	24	59	2	4	5
*	Trincomali	Winckworth	24	57	1	5	5
14t	Phuket Isld.	Brandt	21	57	3	4	4
14m	Medan	Hüner	18	55	–	5	–
14a	Andaman Islds.	A. W. King	24	59	5	4	4
	Andaman Islds.	Sandys	23	58	3	3	4
	Aves Isld.	Winckworth	17	–	4	2	5
	Interview Isld.	Winckworth	17	57	4	1	1
	Nankauri	Winckworth	21	–	1	2	4
*	Port Blair	Winckworth	21	57	4	2	5
14s	Pulo Weh	Buitendijk	21	55	–	4	–
	Nias Isld.	Schröder	21	58	4	4	2
	Padang	de Priester	20	56	1	4	4
	Oosthaven	de Priester	22	56	–	5	3
14j	Labuan	de Priester	19	55	4	4	3
*	Tjilaut Eureun	de Priester	21	56	5	4	3
	Tjilatjap	de Priester	23	58	–	–	–
15d	Darwin: Lee Pt.	L. Watson	30	56	5	1	3
15b	Sunday Isld.	(Perth)	28	58	5	2	2
	Broome	(Schelechoff)	24	59	3	1	4
	Broome	(Uetz)	27	59	5	1	3
*	Willie Creek	Kalnins	22	59	5	1	3
*	Quandong	Kalnins	22	58	5	1	3
*	Gantheaume Pt.	Kalnins	25	58	5	1	4
*	Black Ledge	Kalnins	26	57	4	1	3
15e	Port Hedland	(Schelechoff)	22	57	4	1	4
	Port Samson	B. Wilson	28	57	4	1	3
	Dampier Arch.	Davena Exp.	22	56	4	1	2
54h	Lord Howe Islds.	(Melbourne)	28	57	4	2	3
47s	Avoca: Norah Head	W. Krause	25	57	–	1	3
47b	Woolgoolga	W. Krause	24	56	4	3	3
*	Moreton Bay	Schelechoff	32	57	4	1	4
	Caloundra	Schelechoff	32	56	5	2	4
	Mooloolaba	Lee & Matcott	24	57	4	2	3
47c	Lady Elliott Isld. "61"	Schelechoff	24	59	3	1	2
	Lady Elliott Isld. "65"	Schelechoff	26	56	3	4	3
	Mast Head Isld.	(Melbourne)	25	56	4	1	2
*	One Tree Isld.	Coucom	25	58	5	1	2
	Heron Isld.	(Melbourne)	22	57	5	1	1
	Tryon Isld.	(Summers)	24	58	5	1	1
	Fitzroy Reef	Coucom	28	56	5	1	1
	Humpy Isld.	Coucom	28	56	5	1	3
*	Middle Isld.	Coucom	28	56	5	1	4
*	Pumpkin Isld.	Coucom	26	56	5	2	3
*	North Keppel Isld.	Coucom	26	56	5	1	3
	Conical Isld.	Coucom	29	55	5	2	4
	Piccaninny Pt.	Coucom	30	57	3	3	4
	Double Heads	Coucom	35	55	4	3	3
	Yeppoon (before 1954)	(Summers)	30	56	4	2	3
	Yeppoon (after 1954)	Rita Mada	30	57	5	3	4
	Seaforth	Matcott	29	60	4	4	4
	Mackay	Matcott	29	57	4	1	4
	Mackay: Shell Pt.	Griffiths	28	58	5	3	3
	Finlayson	Griffiths	26	54	4	1	3
	Shute Harbour	W. Krause	25	57	5	2	3
*	Proserpine: Dingo Bay	(Schelechoff)	23	57	4	3	4
*	Penrith Isld.	Houston	23	57	5	1	3
*	Scawfell Isld.	Houston	20	56	5	1	3
*	Hayman Isld.	Uetz	22	59	5	1	3
47q	Bowen	(Summers)	22	58	1	3	3
	Port Denison	(Tomlin)	32	55	4	1	2
	Port Denison	G. W. Young	30	54	4	1	3
	Cairns	(Schelechoff)	22	59	4	4	5
	Green Isld.	Price	17	56	3	1	1
	Buchans Pt.	Price	26	58	3	2	3
46c	New Caledonia	Bougier	23	56	3	3	4
	New Caledonia	Durand	28	59	4	4	1
*	New Caledonia	Rossiter	24	56	4	5	3
	Anse Vata	Cernohorsky	20	58	3	3	3
	Mondoure: shore	Cernohorsky	20	55	3	5	4
	Mondoure: outer reef	Cernohorsky	19	55	4	4	3
46f	Cuvu	Cernohorsky	21	56	2	4	4
*	Vuda Pt.	Cernohorsky	21	57	3	3	4
*	Vatia Wharf	Cernohorsky	20	55	3	4	3
	Manava Isld.	Cernohorsky	19	56	2	1	3

Table 2 [Continued]

			L	BL	DB	AS	BC
	Caboni	Cernohorsky	21	57	3	3	4
	Nananu-i-Ra	Cernohorsky	19	56	4	3	3
	Vitilevu Bay	Cernohorsky	18	56	3	3	4
	Lodoni	Cernohorsky	18	57	3	3	4
	Bau Isld.	Sixten Bock	20	56	2	2	3
	Namuka	Sixten Bock	22	57	1	3	2
46t	Vavau	Cordeira	26	57	1	4	2
	Haapai	Cordeira	19	56	1	4	4
41s *	Malaita: Ata'a	van der Riet	25	55	4	3	3
41b	New Britain: Vuatom	O. Meyer	21	54	3	2	–
	New Britain: Ulamona	J. Schneider	19	54	4	2	2
	Admiralty Islds.	(Melbourne)	22	56	4	1	3
41g	Roon Isld.	Deelder	21	53	5	4	3
	Manokwari	Jochim	19	55	4	4	2
48m	Sorong	Barton	20	56	4	4	2
	Sangir Islds.	de Priester	18	55	–	4	–
	Halmahera	Bernstein	25	57	–	–	–
	Menado	de Priester	24	55	–	5	–
	Busak (NW Celebes)	(Leiden)	22	56	4	5	3
*	Amboina	Hoedt	22	55	4	3	3
	Amboina	Koller	22	–	5	4	2
	Amboina	Ledru	23	–	4	1	2
48a	Kaimana (West Irian)	Ahlers	21	55	–	5	2
48t	North Timor	Wienecke	22	55	4	4	–
	Bali	de Priester	24	55	–	4	–
48c	Tijger Islds.	Verdonk	20	55	–	5	–
	Macassar	Semper	32	55	1	4	–
	Macassar	Toxopeus	–	–	4	2	–
*	Gulf of Madjene	van Nisse	20	56	4	5	–
48j	"Indische Zee" (evidently 1 locality)	(Leiden)	21	55	3	4	2
	Madura	Jochim	25	57	4	5	3
	Batavia Bay	de Priester	19	57	4	3	3
	Batavia Bay	id. (Dautzbrg.)	23	–	1	3	–
	Edam Isld.	de Priester	19	56	–	4	–
48s	Singapore	Doria	28	58	4	5	5
	Singapore	Semper	25	55	3	4	–
	Pulo Sakra	Winckworth	26	57	4	4	4
48g	Ko Si-Chang	Orr, Steiner	24	54	5	4	4
*	West of Ban Pe	Brandt	22	56	5	4	3
*	East of Ban Pe	Brandt	23	55	5	4	3
48p	Zamboanga	Semper	25	–	3	4	3
	Bohol: Ubay	Semper	22	55	4	4	2
	Bohol: Panglao	Semper	20	56	5	1	2
	Cebu	Ringe	18	56	3	4	2
	Samar	Jagor	24	61	2	2	4
	Batangas	Tucker	18	56	4	4	4
	Palawan	Clover	19	55	5	4	3
48v	Pulo Condor	Bavay	30	53	3	2	3
49r	Okinawa: Kue	C. Young	21	56	4	3	3
49s	Tosa	Azuma	30	56	4	4	3
42p	Palau Islds.	(Godeffroy)	27	–	4	2	2
	Palau Islds.	Semper	21	54	5	1	2
	Yap Isld.	Volkens	22	61	1	3	5
42c	Truk Isld.	M. Hill	22	53	1	2	2

FREQUENCY OF MEDIANS

The frequency of the 6 classes distinguished in the 5 recorded characters is illustrated by Table 3.

Table 3

	1	2	3	4	5	6
L	19	25	28	24	20	16
BL	9	25	37	28	14	12
DB	12	5	24	48	32	–
AS	35	21	22	38	15	–
BC	6	22	50	32	7	–

The extreme classes 1 and 6 are well represented in L and BL because they comprise more millimeters or % than the central classes; in the characters of color, however, the extreme class 6 is never represented as median. In L, BL, and BC the maximum figure is in class 3, whereas in the two characters of markings (DB and AS) there are evidently 2 maxima of each in class 1 (markings mostly absent) and 4 (markings mostly rather large); the intermediate classes 2 and 3 are less frequent.

CORRELATION OF CHARACTERS

The correlation of the medians of various pairs of characters indicated in Table 2 may be illustrated by the 6 squares of Table 4.

(see page 111 for Table 4)

There is no distinct correlation between any pair of the characters tabulated in Table 4. The average greater breadth of populations of medium classes of length than of extreme classes must be regarded as random; there is no correlation in L : DB nor in BL : BC; the slightly negative correlation in DB : AS and in DB : BC also cannot be proved mathematically, as well as the slightly positive correlation in AS : BC. In any case, there is no general parallelism in accumulation of pigment in the 3 characters DB, AS, and BC (see also F. A. & M. SCHILDER, 1961, p. 304).

INDIVIDUAL VARIATION

The individual variation within extreme populations may be illustrated by Table 5; the figures indicate the number of specimens belonging to each class of the character.

Table 4

breadth \ length	1	2	3	4	5	6
6	–	–	4	5	2	1
5	–	2	4	3	4	1
4	3	4	5	7	5	4
3	8	9	6	3	7	4
2	6	6	5	4	–	4
1	1	3	1	1	1	2

dorsal blotch \ length	1	2	3	4	5	6
6	–	–	–	–	–	–
5	1	5	8	6	8	4
4	9	5	10	6	9	8
3	4	8	2	4	2	4
2	1	2	–	2	–	–
1	1	2	5	2	1	1

basal color \ breadth	1	2	3	4	5	6
6	–	–	–	–	–	–
5	–	–	–	2	1	3
4	1	3	9	12	2	4
3	4	8	19	9	6	3
2	3	5	5	2	3	1
1	–	–	2	2	1	1

anterior spots \ dorsal blotch	1	2	3	4	5	6
6	–	–	–	–	–	–
5	2	–	2	6	–	–
4	4	2	7	13	8	–
3	4	–	8	8	2	–
2	2	2	4	8	5	–
1	–	1	3	13	17	–

basal color \ dorsal blotch	1	2	3	4	5	6
6	–	–	–	–	–	–
5	2	1	–	4	–	–
4	4	2	11	8	7	–
3	1	2	7	21	17	–
2	3	–	3	10	5	–
1	–	–	1	2	3	–

basal color \ anterior spots	1	2	3	4	5	6
6	–	–	–	–	–	–
5	–	2	1	2	2	–
4	6	4	9	9	4	–
3	16	9	10	11	4	–
2	8	4	1	7	1	–
1	5	–	–	1	–	–

Table 5

Charact.	Locality	Class 1	2	3	4	5	6	median
L [1]	Vatia Wharf	48	24	18	4	–	2	2
	Moreton Bay	–	–	–	–	2	44	6
BL [1]	Malaita: Ata'a	82	45	32	17	5	2	2
	Willie Creek	2	4	7	13	20	49	6
DB	Trincomali	38	20	13	6	2	1	1
	Hayman Isld.	–	–	8	17	35	4	5
AS	Black Ledge	54	8	6	9	1	–	1
	Trincomali	1	4	10	19	32	14	5
BC	One Tree Isld.	–	79	4	–	–	–	2
	Port Blair	–	–	6	29	51	21	5

[1] The individual extremes in the measurable characters are L = 15 to 39 mm and BL = 50 to 65% in the 133 populations.

These figures establish that there are really significant differences between populations. On the other hand, adjacent populations show great resemblance in many characters, even if they live under different ecological conditions. This fact may be illustrated in Table 6 by 4 populations from an area of 41 miles around Broome: the distance between the 4 localities Willie Creek (95 shells), Quandong (74 shells), Gantheaume Point (85 shells), and Black Ledge (80 shells) is about 15, 15, and 11 miles respectively (according to Mr. A. Kalnins); Gantheaume Point is a rocky coast, Black Ledge is a muddy reef (F. A. Schilder, 1968a, 1968b).

Table 6 shows that the distribution of the 3 characters in color (DB, AS, BC) is very similar in these 4 populations, as it may be caused by a common gene pool in the whole area of 41 miles, whereas the size (L) and relative breadth (BL) show great local differences which may be influenced by environmental conditions of the habitat. Besides, there is a distinct negative correlation between length and relative breadth in these 4 populations.

Table 6

		1	2	3	4	5	6 [2]
L	Willie Creek	8	24	***27***	22	13	1
	Quandong	11	14	***29***	16	4	–
	Gantheaume Pt.	–	16	15	***27***	23	2
	Black Ledge	–	1	13	15	***33***	7
BL	Willie Creek	2	4	7	13	20	***41***
	Quandong	–	2	8	16	***20***	28
	Gantheaume Pt.	–	1	15	18	***21***	29
	Black Ledge	3	7	10	***21***	24	14
DB	Willie Creek	6	4	14	21	***38***	12
	Quandong	4	8	3	12	***32***	15
	Gantheaume Pt.	1	2	3	15	***47***	17
	Black Ledge	9	5	11	***19***	24	10
AS	Willie Creek	***53***	9	11	17	4	1
	Quandong	***42***	9	8	11	4	–
	Gantheaume Pt.	***49***	5	11	14	6	–
	Black Ledge	***54***	8	6	9	1	–
BC	Willie Creek	2	12	***57***	21	2	1
	Quandong	2	13	***34***	14	10	1
	Gantheaume Pt.	3	11	27	***30***	13	1
	Black Ledge	1	13	***41***	20	4	1

[2] The medians are printed in *italics*.

Sexual differences exist in the relative breadth (BL) only, as according to previous studies the females of *Erronea errones* are about one class broader than the males, whereas the other characters show no sexual differences (Schilder & Houston, 1964, tables 3 and 4).

LOCAL POLYMORPHISM

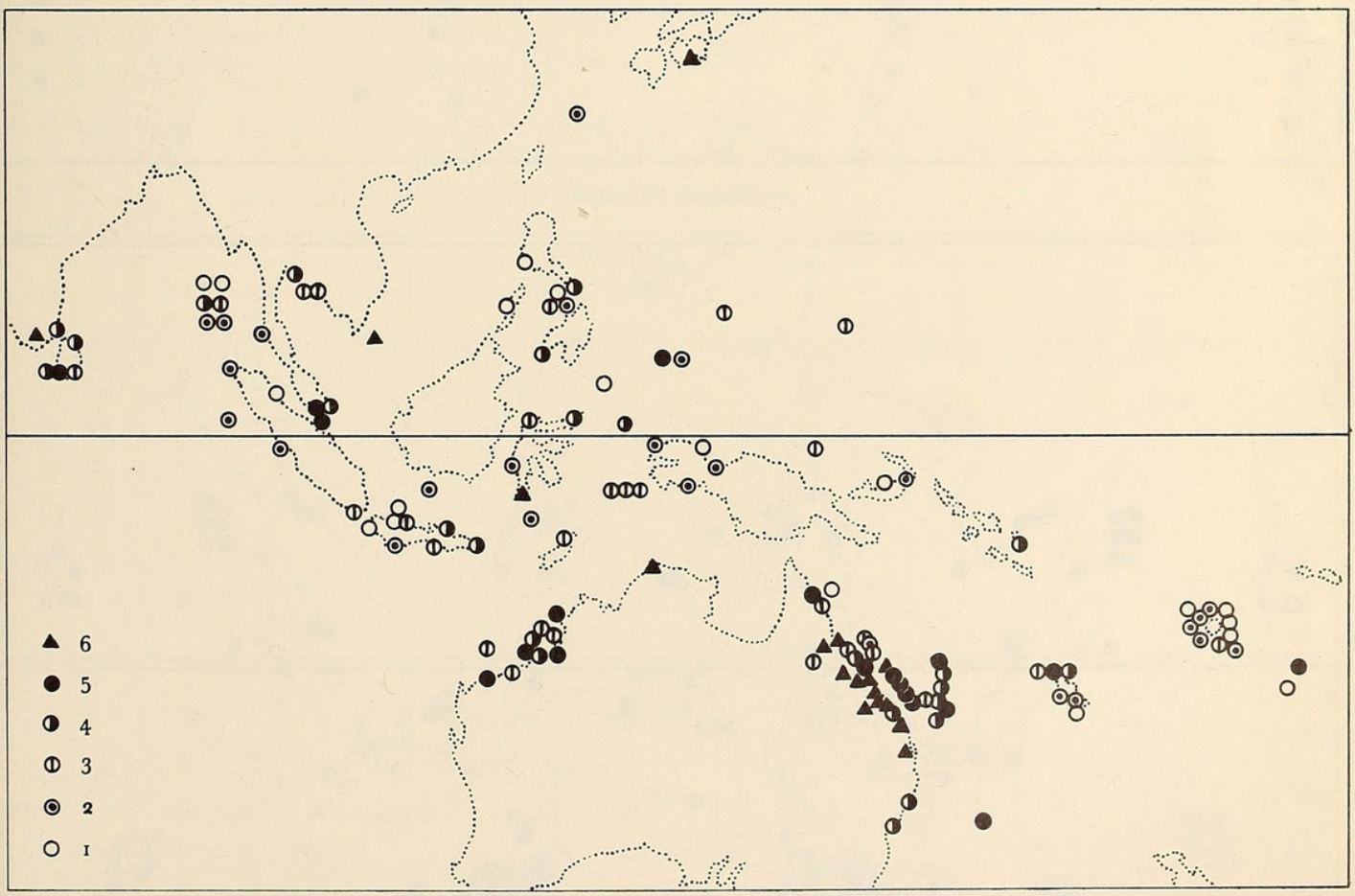
The only real mutant concerns the sky-blue absolutely unspotted variant living in the populations 26 miles around Broome, but never collected elsewhere (F. A. SCHILDER, 1968 a); it lives with usual specimens of *Erronea errones* without producing intermediates, and constitutes 1 to 6% in all populations around Broome. This morphe has been called *azurea* SCHILDER (1968 b).

All other extreme varieties, e. g. the subrostrate melanistic shells (New Caledonia, Pumpkin Island, One Tree Island, etc) or those with the labial anterior spot produced along the margin or even rare shells with one or two posterior terminal spots must be regarded as extreme individual aberrations connected with the normal specimens by many intermediates. Shells showing the dorsum suffused with a layer of unspotted pale enamel should be regarded as pathological, as this accessory layer mostly includes particles of mud or even parasites, and the usual markings are shining through; they occur scattered in many populations, but seem to accumulate in some populations living under special conditions.

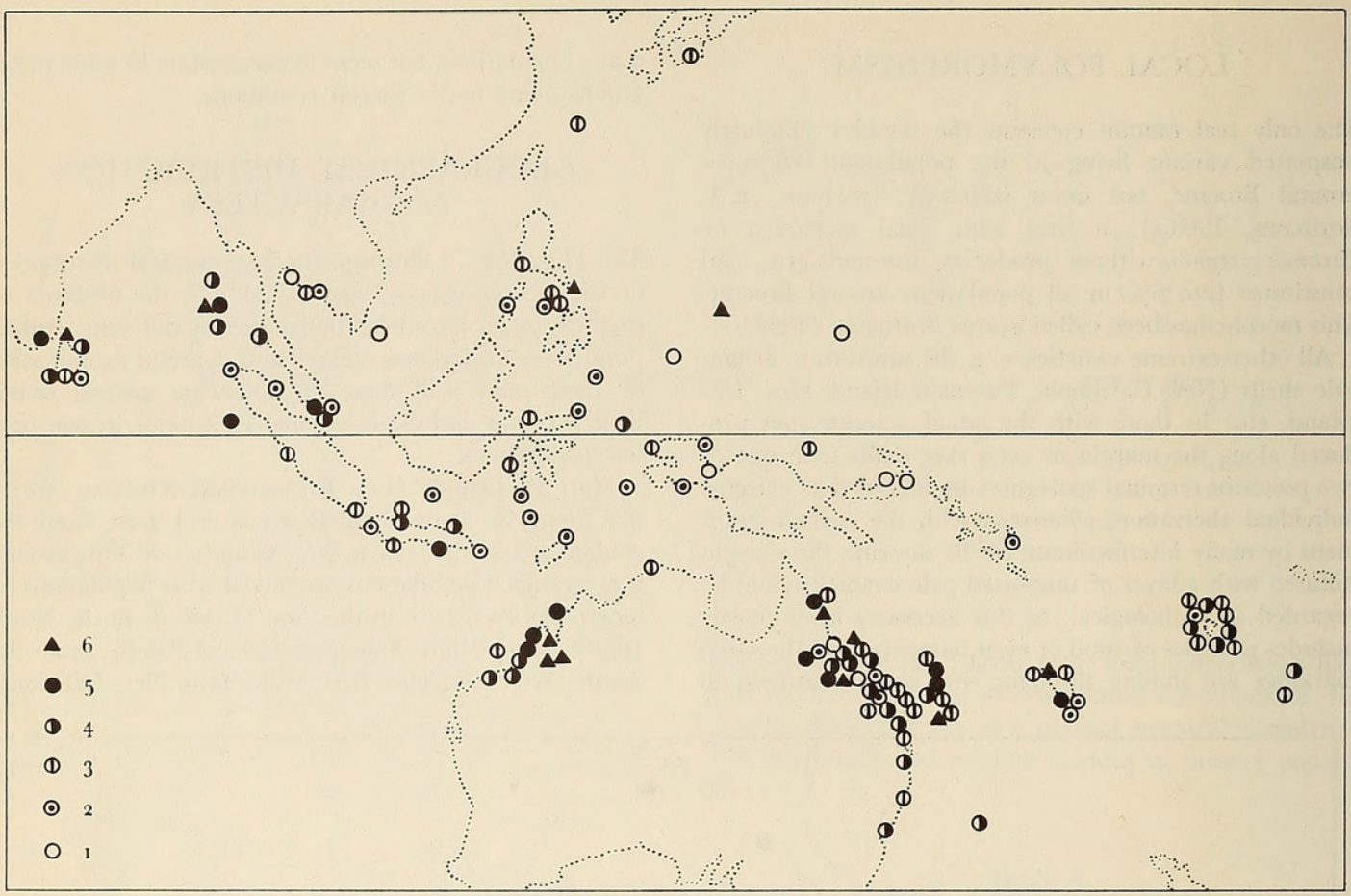
GEOGRAPHICAL DISTRIBUTION OF CHARACTERS

The Maps 1 to 5 illustrate the geographical distribution of the median classes listed in Table 2; the 6 classes of each character have been designated by different symbols progressive in darkness from 1 to 6. Careful examination of these maps will show the following general trends which do not exclude occasional exceptions in one or a few populations.

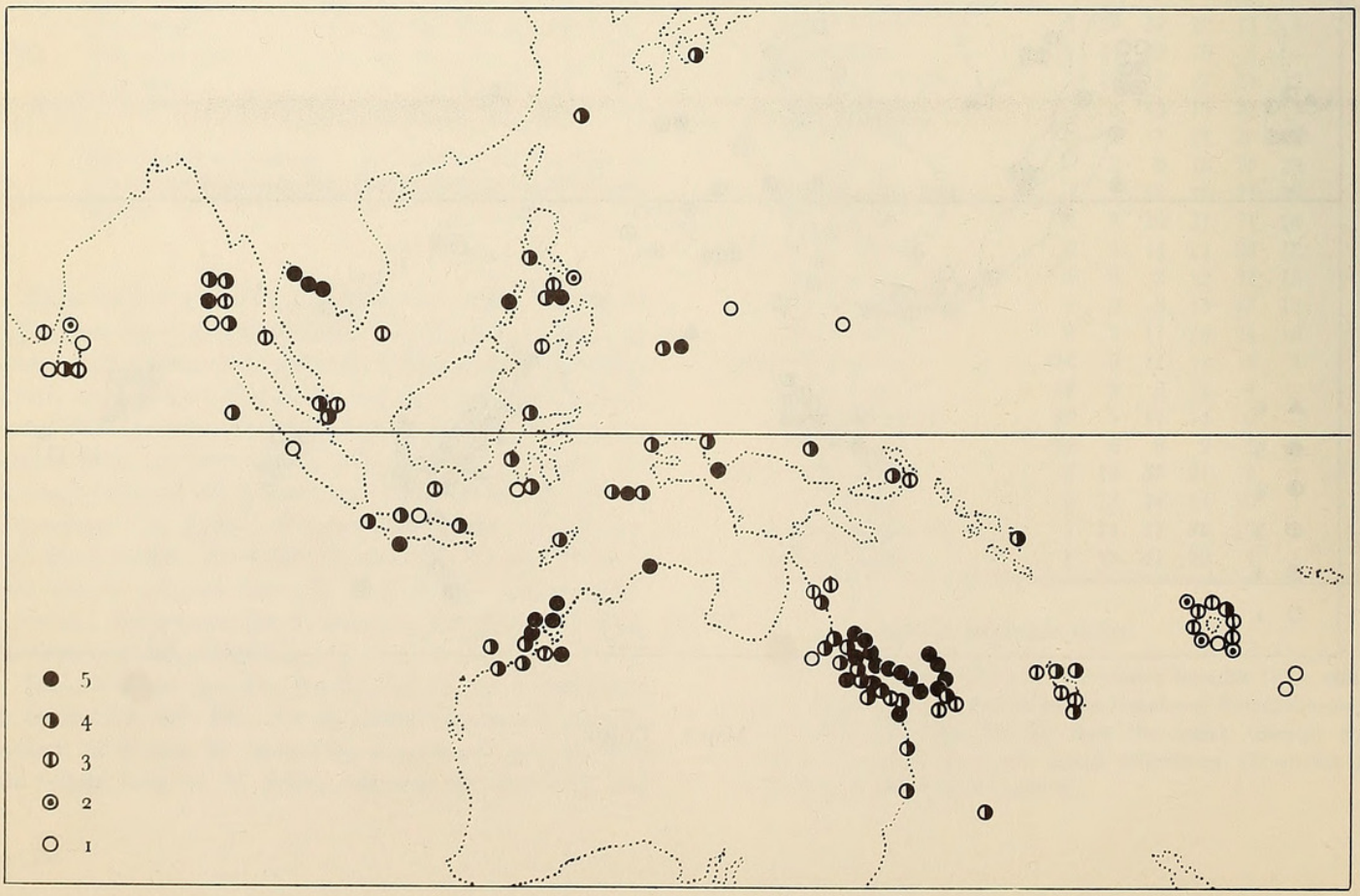
Map 1: Length (L). The smallest *Erronea errones* live along an approximately equatorial zone from the Andaman Islands to Java, New Guinea, and Fiji; around this zone such populations are mixed with populations of larger specimens, viz. in the West (Ceylon), in the North (north of the line Singapore-Celebes-Palau), and the South (West Australia, East Australia to New Caledonia



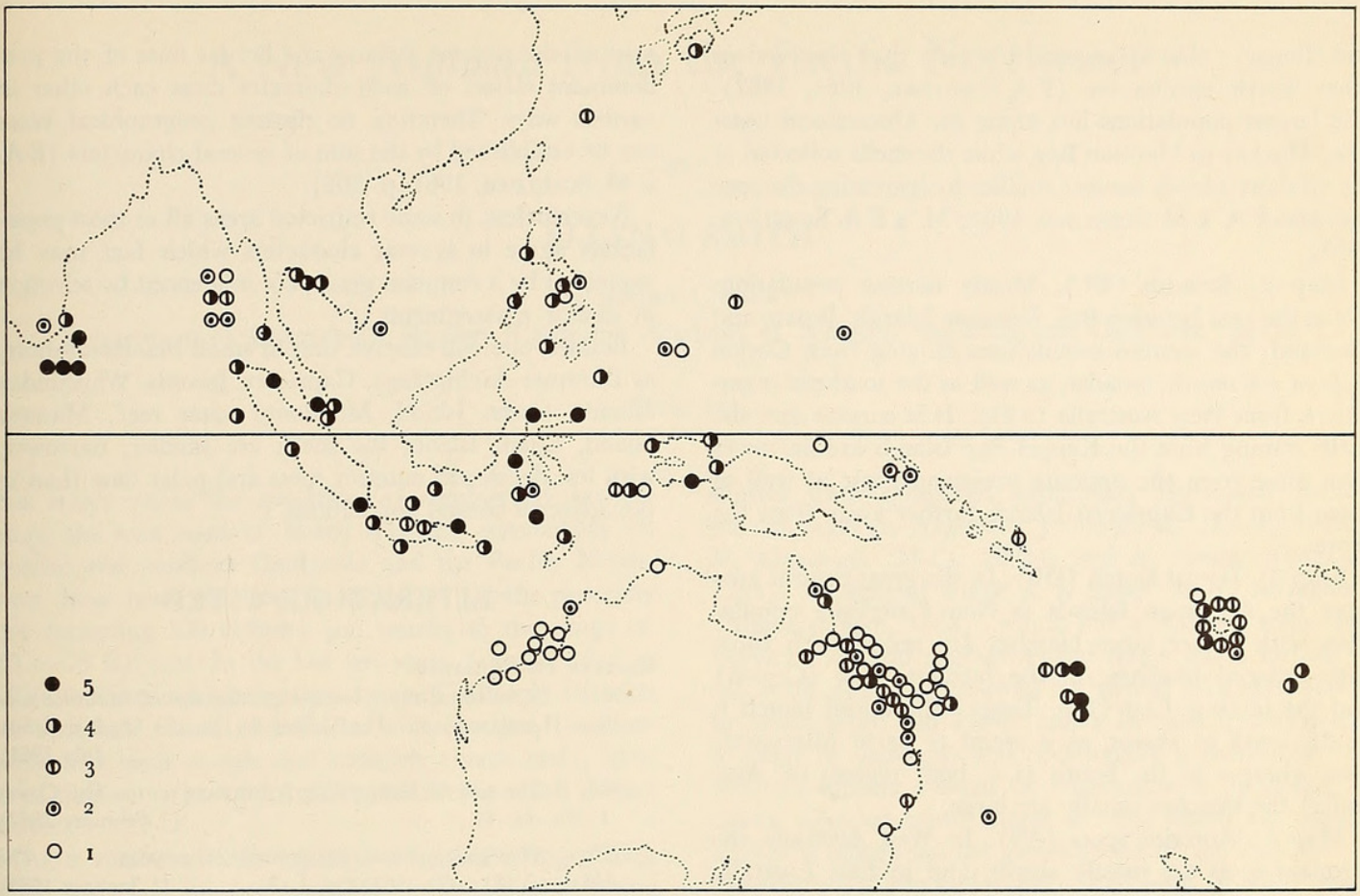
Map 1: Length



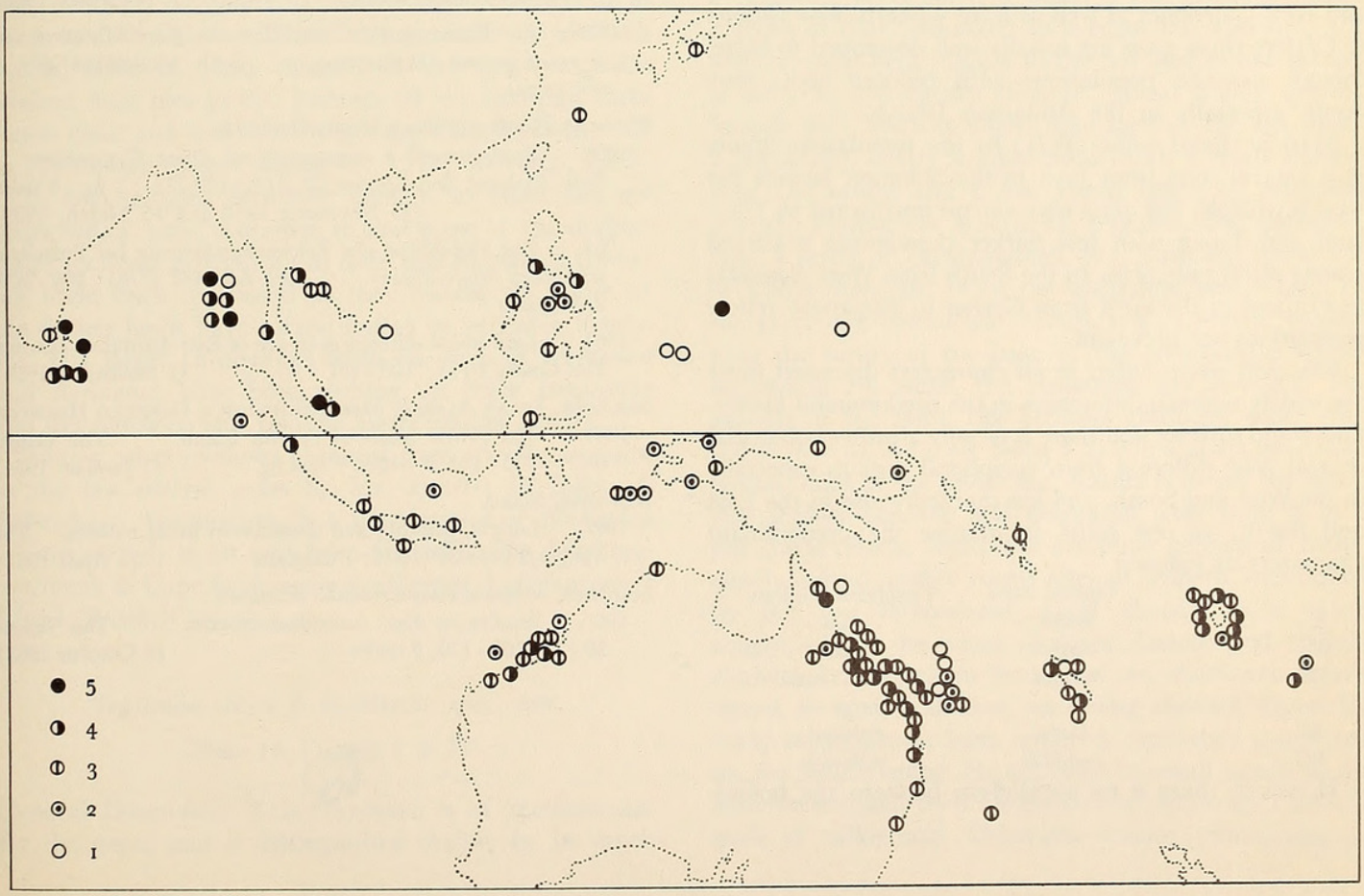
Map 2: Breadth



Map 3: Dorsal Blotch



Map 4: Anterior Spots



Map 5: Basal Color

and Tonga): this arrangement recalls that observed in other cowrie species too (F. A. SCHILDER, 1961, 1962). The largest populations live along the Queensland coast from Mackay to Moreton Bay, while the shells collected at the off-shore islands become smaller by increasing distance (see also F. A. & M. SCHILDER, 1964; M. & F. A. SCHILDER, 1967).

Map 2: Breadth (BL). Mostly narrow populations live in the area between Bali, Solomon Islands, Japan, and Thailand; the western populations ranging from Ceylon to Java are mostly broader, as well as the southern populations from West Australia to Fiji. It is curious that the shells coming from the Keppel Bay Islands are narrower than those from the opposite mainland coast as well as those from the Capricorn Islands farther away from the shore.

Map 3: Dorsal blotch (DB). In the great central area from the Andaman Islands to New Caledonia populations with rather large blotches are mixed with those with reduced blotches; in the farthest West (Ceylon) and the farthest East (Fiji, Tonga) the dorsal blotch is mostly small to absent, as it seems to be in Micronesia also, whereas in the South (i. e. both regions of Australia) the blotches usually are large.

Map 4: Anterior spots (AS). In West Australia the terminal spots are mostly absent, and in East Australia they are small, as well as from the Admiralty Islands to Fiji and Micronesia; in the central zone, i. e. in Tonga and New Caledonia as well as from western New Guinea to Ceylon, these spots are usually well developed to large, though sporadic populations with reduced spots may occur, especially in the Andaman Islands.

Map 5: Basal color (BC). In the populations living in a central zone from Java to the Solomon Islands the base is whitish; this zone may extend northward to Thailand and Japan with few darker populations scattered among many pale ones. In the South from West Australia to Fiji and in the West from Ceylon to Singapore yellow populations are prevalent.

One will observe that in all characters discussed there are widely regional differences in the predominant classes. One could surmise that there is usually a rather equatorial central zone differing from peripheral regions especially in the West and South, and less markedly also in the East and North: so one could summarize the predominant characters as follows:

	Central Zone	Peripheral Regions
L	small	large
BL	narrow	broad
DB	various	N, W, E: small S: large
AS	large	reduced
BC	whitish	yellowish

However, there is no parallelism between the boundaries of the regions, because the border lines of the predominant classes of each character cross each other in various ways. Therefore no distinct geographical races can be established by the sum of several characters (F. A. & M. SCHILDER, 1961, p. 305).

Nevertheless, in some restricted areas all or most populations agree in several characters which fact may be explained by a common gene pool influenced by selection in similar environments.

Besides, one will observe that in small islands off-shore, as Dampier Archipelago, Capricorn Islands, Whitsunday Islands, Green Island, Mondoure outer reef, Manava Island, Edam Island, the shells are smaller, narrower, with less developed anterior spots and paler base than in the adjacent coastal populations.

LITERATURE CITED

SCHILDER, FRANZ ALFRED

1961. A statistical study in cowries: the size of *Mauritia arabica* (LINNAEUS). The Veliger **4** (1): 15 - 17; 2 text figs. (1 July 1961)

1962. The size of *Cypraea tigris* LINNAEUS. The Cowry **1** (3): 43 - 44 (1 February 1962)

1965. The geographical distribution of cowries. The Veliger **7** (3): 171 - 183; figs. 1 - 3 (1 January 1965)

1968a. An interesting mutation in cowries. Hawaiian Shell News (n. s.) **98**: 5; 1 fig. (February 1968)

1968b. Zur Kenntnis der Cypraeidae: 13. Eine Mutation von *Erronea errones* (LINNAEUS). Arch. Molluskenk. **97**: (in press)

SCHILDER, FRANZ ALFRED, & MARIA SCHILDER

1938. Prodrome of a monograph on living Cypraeidae. Proc. Malacol. Soc. London **23** (3/4): 119 - 231; 1 fig.; 9 maps (15 November 1938 and 15 March, 1939)

1961. Zur Variabilität der Zeichnungselemente bei Porzellanschnecken (Cypraeidae). Zool. Anz. **167** (7/8): 303 - 309; 2 diagrams

1964. Latitudinal differences in size of East Australian cowries. The Cowry **1** (7): 100 - 101 (1 November 1964)

SCHILDER, FRANZ ALFRED, MARIA SCHILDER & GARFIELD HOUSTON

1964. The cowrie fauna of Penrith Island. The Veliger **6** (3): 155 - 161; 4 tables; 1 text fig. (1 January 1964)

SCHILDER, MARIA

1967. Length, breadth, and dentition in living cowries. The Veliger **9** (4): 369 - 376; 1 diagram (1 April 1967)

SCHILDER, MARIA & FRANZ ALFRED SCHILDER

1967. Studies on East Australian cowries. The Veliger **10** (2): 103 - 110; 9 tables (1 October 1967)