THE GROWTH RATE AT VARIOUS DEPTHS OF CORAL REEFS IN THE DUTCH EAST INDIAN ARCHIPELAGO.

By

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With the intention to obtain data about the rate of growth of coral reefs in the East Indian Archipelago, the depths of a number of reefs, as they were found during the first hydrographic survey, were compared with the depths found during the newest surveys. The reefs in question were situated in the Gulf of Tomini (North Celebes) and in the Kei-islands (S. W. of Papua). My original intention was no other than to obtain data for the use of seamen in connection with the use of charts based on surveys of several years ago. Dr. J. VERWEY, Laboratorium voor het Onderzoek der Zee, Batavia, assured me, however, that the data collected by me, were of great scientific interest, especially if it were possible to give more particulars about the reefs surveyed, e.g. the difference in growth rate between reefs at depths of 10, 20, 30 m, etc. As my inquiry was not made for scientific purposes, I cannot furnish these details, but I insert a list of all the figures on which the comparison was based.

My notes concerning the reefs of the coast of the Gulf of Tomini (the Bight of Tomini) have been successively gathered during the new hydrographic survey (1930-'31). In collecting them I made no notes on geographical longitude and latitude of the reefs and as the old and new surveys have been drawn on a different scale, it is very difficult to find out the longitude and latitude of each reef among the tens of thousands of localisations during the sounding work. These data were in my opinion of no interest. Moreover, it appeared later that the difference in average growth rate between reefs in the two parts of the Gulf of Tomini is not worth mentioning. — As to the Togian and Kei Islands, however, the positions are given (see map). So called provisional charts were not used for the comparison, as it cannot always be said with certainty, that during the provisional surveys the smallest depths were found, and just the smallest dephts found on each reef form my base of comparison.

In behalf of those not acquainted with hydrographical survey work, the following particulars are given to judge about the exactness of the recorded data. Though it is generally very difficult in a hydrographical survey to say with absolute certainty that all existing dangers to navigation have been found, it may be said that the shallowest place of any reef discovered is almost
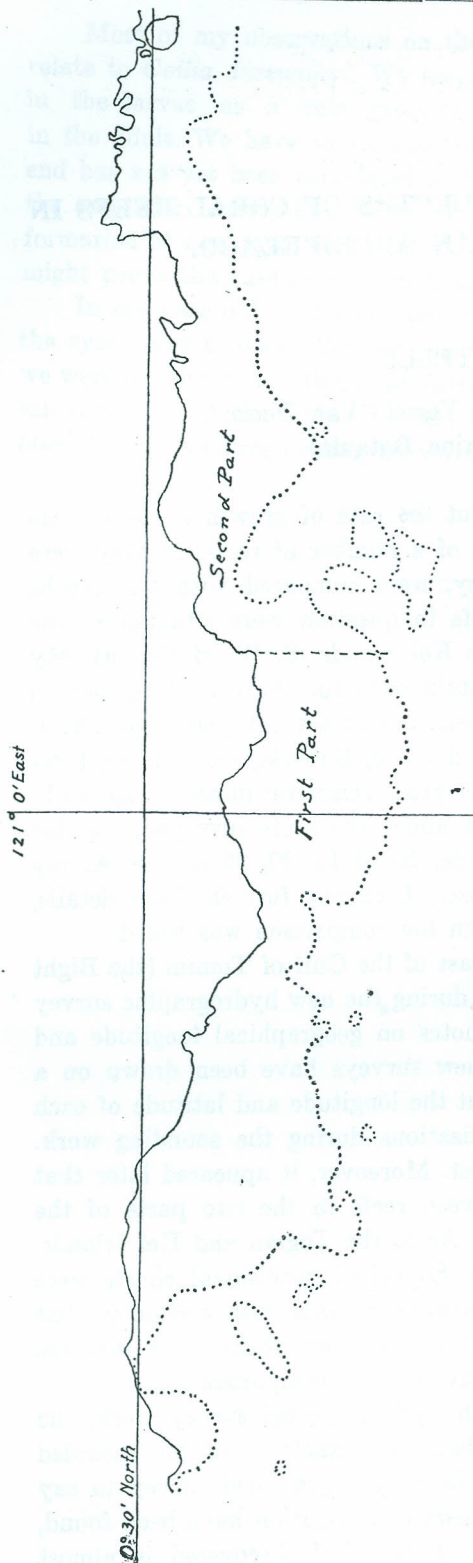
certainly found, because it is searched for during a long time, as it is of very great interest to the sailor. — During both the early and the later surveys all depths have been reduced to the same level, lying at a certain distance below mean sea level. The vertical motion of the water in respect to mean level is calculated by harmonic analysis (constituents used: S 2, M 2, K 1, O 1, P 1, N 2, K 2). The base of comparison, then, can be considered as sufficiently correct.

It needs not be emphasized that reefs, the identity of which during both surveys could not be verified with absolute certainty, were not used for comparison. On account of the great number of newly discovered reefs, it was often difficult to obtain this certainty.

As already stated the reefs compared are situated in the Gulf of Tomini and the Kei Islands. Those in the Gulf of Tomini fall into two groups: 1. those of the Bight of Tomini, 2. those of the Togian Islands in the Gulf of Tomini.

The reefs of the Gulf of Tomini (those of the Togian Islands included) for the study of which sea charts nrs. 60 and 308 and the white prints from the new survey were used, are without exception very steep. They rise up from depths of 20 to 40 metres, while at a distance of 100 to 400 metres from the reefs on the edge of the continental shelf, depths of more than 200 m were recorded. The reefs of the Kei Islands, which were studied by comparing Dutch chart nr. 162 (Hydrog. Survey 1890) and white print 1495 (Hydrogr. Survey 1927), are not so steep.

Sketches are added of the areas in which the reefs used are situated; the order of exploration, has been from West to East. For the sake of convenience the material available is divided as given below.

It should be stated that the average figures given for the Bight of Tomini are not quite the same as those given in De Zee, Vol. 5/1931; the reason is that I have added some figures and that some others have not been used here.

A. **TOGIAN ISLANDS**	1° Reefs with depths during first survey of less than 3 metres	on the edge of continental shelf	a) rising
			b) sinking
		not on the edge of continental shelf	a) rising
			b) sinking
	2° Reefs with depths during first survey of 3—5 metres	subdivided as 1°	
	3° Reefs with depths during first survey of more than 5 metres	subdivided as 1°	
B. I. **Gulf of TOMINI** **(first part)**	1° Reefs with depths during first survey of less than 3 metres		a) rising
			b) sinking
	2° Reefs with depths during first survey of 3—5 metres		subdivided as 1°
	3° Reefs with depths during first survey of more than 5 metres		subdivided as 1°
B. II. **Gulf of TOMINI** **(second part)**	subdivided as B. I.		
C. **KEI-ISLANDS**	subdivided as B. I.		

I hope that the data collected by me may serve as an addition to the knowledge of the growthrate of coralreefs in other countries.

A. TOGIAN ISLANDS. 1° DEPTHS < 3 METRES.

RISING				SINKING			
Reef nr.	Smallest depth survey 1905	Smallest depth survey 1929	Amount of rising	Reef nr.	Smallest depth survey 1905	Smallest depth survey 1929	Amount of sinking
I Reefs on the edge of continental shelf				**I** Reefs on the edge of continental shelf			
44	1,75 mr	dry	1,75	7	1,75	2,0	0,25
57	1,75	1,0	0,75	11	1,75	2,0	0,25
65	1,75	dry	1,75	20	dry	1,50	1,50
70	2,75	2,50	0,25	22	dry	0,25	0,25
71	1,75	1,50	0.25	23	dry	0,50	0,50
			4,75	24	dry	1,00	1,00
				43	1,75	2,00	0,25
							4,00

Mean per annum: $\frac{475}{5\times24} = 4{,}0$ cm

Mean per annum: $\frac{400}{7\times24} = 2{,}4$ cm

II Reefs not on the edge of shelf				**II** Reefs not on the edge of shelf			
27	1,75	dry	1,75	15	1,75	2,50	0,75
32	1,75	dry	1,75	29	1,75	2,00	0,25
59	1,75	1,50	0,25	31	2,75	3,00	0,25
67	1,75	dry	1,75	33	1,75	3,50	1,75
			5,50	36	1,75	4,00	2,25
				38	dry	1,00	1,00
				42	1,75	2,50	0,75
				50	1,75	2,00	0,25
							7,25

Mean per annum: $\frac{550}{4\times24} = 5{,}7$ cm

Mean per annum: $\frac{725}{8\times24} = 3{,}8$ cm

Mean of I and II: 4,7 cm p.a.   Mean of I and II: 6,3 cm p.a.

A. TOGIAN ISLANDS. 2° DEPTHS 3-5 METRES.

I Reefs on the edge of continental shelf				**I** Reefs on the edge of continental shelf			
8	3,50	0,25	3,25	19	3,50	4,00	0,50
25	3,50	dry	3,50	21	3,50	5,00	1,50
66	3,50	0,50	3,00				2,00
			9,75				

Mean per annum: $\frac{975}{3\times24} = 13{,}5$ cm

Mean per annum: $\frac{200}{2\times24} = 4{,}2$ cm

II Reefs not on the edge of shelf				**II** Reefs not on the edge of shelf			
34	3,50	2,00	1,50	48	4,50	6,00	1,50
37	3,50	2,00	1,50	61	3,50	6,00	2,50
54	4,50	3,50	1,00				4,00
58	3,50	1,00	2,50				
62	3,50	dry	3,50				
			10,00				

Mean per annum: $\frac{1000}{5\times24} = 8{,}3$ cm

Mean per annum: $\frac{400}{2\times24} = 8{,}3$ cm

Mean of I and II: 10,3 cm   Mean of I and II: 6,3 cm

A. Togian Islands. 3° Depths > 5 metres

	RISING				SINKING		
Reef nr.	Smallest depth survey 1905	Smallest depth survey 1929	Amount of rising	Reef nr.	Smallest depth survey 1905	Smallest depth survey 1929	Amount of sinking
I Reefs on the edge of continental shelf				I Reefs on the edge of continental shelf			
1	5,50	2,50	3,00	5	7,25	8,00	0,75
2	9,00	dry	9,00	39	10,75	13,00	2,25
4	7,25	4,00	3,25	40	9,00	10,00	1,00
6	9,00	5,00	4,00	45	10,75	12,00	1,25
9	7,25	5,50	1,75	47	5,50	7,00	1,50
10	9,00	3,00	6,00	72	10,75	11,00	0,25
12	9,00	5,00	4,00				7,00
14	5,50	3,00	2,50				
16	14,50	13,00	1,50	Mean per annum $\dfrac{700}{6\times24}$ = 4,9 cm			
17	5,50	3,50	2,00				
18	7,25	7,00	0,25				
41	6,25	6,00	0,25				
52	6,25	6,00	0,25				
53	6,25	6,00	1,25				
68	5,50	dry	5,50				
69	10,75	1,00	9,75				
			54,25				

Mean per annum $\dfrac{5425}{16\times24}$ = 14,1 cm

	RISING				SINKING		
II Reefs not on the edge of shelf				II Reefs not on the edge of shelf			
3	5,50	4,00	1,50	46	7,25	8,00	0,75
13	5,50	4,00	1,50	56	5,50	7,00	1,50
26	7,25	2,50	4,75	60	5,50	7,00	1,50
28	9,00	6,00	3,00				3,75
30	9,00	7,00	2,00	Mean per annum $\dfrac{375}{3\times24}$ = 5,2 cm			
35	5,50	1,50	4,00				
49	10,75	1,00	9,75				
51	9,00	8,00	1,00				
55	10,75	7,00	3,75				
63	5,50	dry	5,50				
			36,75				

Mean per annum $\dfrac{3675}{10\times24}$ = 15,3 cm

Mean of I and II = 14,6 cm   Mean of I and II 5,0 cm

B.　GULF OF TOMINI. FIRST PART. 1° DEPTHS < 3 METRES.

RISING			SINKING		
Smallest depth survey 1905	Smallest depth survey 1930	Amount of rising	Smallest depth survey 1905	Smallest depth survey 1930	Amount of sinking
0,75	0,25	0,50	1,50	2,50	1,00
dry	+ 0,75 dry	0,75	1,75	2,50	0,75
1,75	1,25	0,50	0,75	4,00	3,25
1,75	1,00	0,75	0,75	2,25	1,50
1,25	0,50	0,75	0,75	1,00	0,25
2,75	2,00	0,75			6,75
1,50	dry	1,50			
0,75	dry	0,75			
1,75	0,75	1,00			
1,25	dry	1,25			
1,75	1,50	0,25			
1,25	0,75	0,50			
1,75	1,00	0,75			
0,50	dry	0,50			
0,50	0,25	0,25			
0,75	dry	0,75			
2,75	dry	2,75			
1,50	+ 0,25 dry	1,75			
2,75	0,75	2,00			
1,75	dry	1,75			
1,75	0,75	1,00			
2,75	2,25	0,50			
1,75	dry	1,75			
0,75	dry	0,75			
2,75	dry	2,75			
0,75	dry	0,75			
1,75	1,00	0,75			
2,75	1,50	1,25			
		29,25			

SINKING Mean per annum $\dfrac{675}{5\times25} = 5,4$ cm

RISING Mean per annum $\dfrac{2925}{28\times25} = 4,2$ cm

B.　GULF OF TOMINI. FIRST PART. 2° DEPTHS 3-5 METRES.

RISING			SINKING		
3,50	1,25	2,25	3,50	4,00	0,50
3,50	2,75	0,75	3,50	4,25	0,75
3,50	1,75	1,75	3,50	5,25	1,75
3,50	3,50	0,00	3,50	3,75	0,25
3,50	2,50	1,00	3,50	4,25	0,75
3,50	2,25	1,25			4,00
3,50	dry	3,50			
3,50	2,50	1,00			
		11,50			

SINKING Mean per annum $\dfrac{400}{5\times25} = 3,2$ cm

RISING Mean per annum $\dfrac{1150}{8\times25} = 5,8$ cm

B. Gulf of Tomini. 3° Depths > 5 metres.

	RISING			SINKING	
Smallest depth survey 1905	Smallest depth survey 1930	Amount of rising	Smallest depth survey 1905	Smallest depth survey 1930	Amount of rising
5,50	3,50	2,00	5,50	6,00	0,50
5,50	2,00	3,50	5,50	6,00	0,50
5,50	5,00	0,50	7,50	8,00	0,50
18,00	11,00	7,00	10,75	12,00	1 25
5,50	4,75	0,75	5,25	6,00	0,75
7,25	5,00	2,25	5,50	7,50	2,00
7,25	3,00	4,25	7,25	8,00	0.75
5,50	dry	5,50			6,25
7,50	6,50	1,00			
5,75	3.25	2,50			
9,50	8,00	1,50			
9,00	7,00	2,00			
9,00	7,50	1,50			
7,25	7,00	0,25			
7,25	7,00	0,25			
5,25	4,00	1,25			
		36,00			

Mean per annum (SINKING) $\dfrac{625}{7\times25} = 3,6$ cm

Mean per annum (RISING) $\dfrac{3600}{16\times25} = 9,0$ cm

B. Gulf of Tomini. Second Part. Depths < 3 Metres.

	RISING			SINKING	
Smallest depth survey 1898	Smallest depth survey 1930	Amount of rising	Smallest depth survey 1898	Smallest depth survey 1930	Amount of sinking
1,00	0,75	0,25	1,00	2,25	1,25
1,00	0,50	0,50	2,75	3,75	1,00
2,75	0,50	2,25	2,00	2,50	0,50
2,00	0,50	1,50	1,00	1,25	0,25
		4,50			3,00

Mean per annum $\dfrac{450}{4\times32} = 3,5$ cm

Mean per annum $\dfrac{300}{4\times32} = 2,3$ cm

B. Gulf of Tomini. Second Part. Depths 3-5 Metres.

3,75	0,25	3,50
3,50	2,75	0,75
3,75	2,00	1,75
3,75	3,50	0,25
4,50	1,25	3,25
3,75	dry	3,75
4,50	2,25	2,25
4,50	3,25	1,25
4,50	2,50	2,00
3,75	2,75	1,00
3,75	dry	3,75
3,75	0,25	3,50
		27,00

No sinking observed.

Mean per annum $\dfrac{2700}{12\times32} = 7,0$ cm

B.   GULF OF TOMINI. SECOND PART. DEPTHS > 5 METRES.

Smallest depth survey 1898	Smallest depth survey 1930	Amount of rising	Smallest depth survey 1898	Smallest depth survey 1930	Amount of sinking
9,00	6,00	3,00	7,25	8,00	0,75
5,50	4,25	1,25	9,00	10,00	1,00
5,50	4,25	1,25			1,75
16,25	16,00	0,25			
5,50	2,00	3,50			
11,00	9,00	2,00			
7,25	3,50	3,75			
9,00	7,50	1,50			
8,25	4,75	3,50			
16,25	11,00	5,25			
6,25	3,25	3,00			
9,00	2,50	6,50			
7,25	1,00	6,25			
18,00	4,75	13,25			
5,50	3,25	2,25			
5,50	2,75	2,75			
5,50	2,25	3,25			
5,50	3,00	2,50			
5,50	4,25	1,25			
9,00	8,00	1,00			
		67,25			

Mean per annum $\dfrac{175}{2\times32} = 2{,}7$ cm

Mean per annum $\dfrac{6725}{20\times32} = 10{,}5$ cm

C.   KEI-ISLANDS. 1° DEPTHS < 3 METRES.

	RISING				SINKING		
Reef nr.	Smallest depth survey 1890	Smallest depth survey 1927	Amount of rising	Reef nr.	Smallest depth survey 1890	Smallest depth survey 1927	Amount of sinking
7	1,00	0,50	0,50	2	dry	0,25	0,25
8	1,00	0,25	0.75	14	0,50	3,00	2.50
			1,25				2,75

Mean per annum $\dfrac{125}{2\times37} = 1{,}7$ cm   Mean per annum $\dfrac{275}{2\times37} = 3{,}7$ cm

C.   KEI-ISLANDS. 2° DEPTHS 3-5 METRES.

1	3,50	3,00	0,50	9	3,50	4,75	1,25
6	4,00	3,50	0,50	15	3,53	5,25	1,75
12	5,00	4,50	0,50				3,00
			1,50				

Mean per annum $\dfrac{150}{3\times37} = 1{,}4$ cm   Mean per annum $\dfrac{300}{2\times37} = 4{,}1$ cm

C. Kei-Islands. 3° Depths > 5 metres.

	RISING				SINKING		
Reef nr.	Smallest depth survey 1890	Smallest depth survey 1927	Amount of rising	Reef nr.	Smallest depth survey 1890	Smallest depth survey 1927	Amount of sinking
3	7,75	5,00	2,75	4	9,00	10,00	1,00
5	9,00	7,00	2,00				1,00
10	5,50	4,50	1,00				
11	9,00	7,50	1,50				
13	7,25	6,00	1,25				
16	6,75	6,00	0,75				
17	9,00	7,50	1,50				
18	12,50	7,00	5,50				
			16,25				

Mean per annum $\frac{100}{1 \times 37} = 2{,}7$ cm

Mean per annum $\frac{1625}{8 \times 37} = 5{,}5$ cm

Recapitulation of the figures of interest gives the following table

		RISING			SINKING		
		mean p.a.	max. p.a.	min. p.a.	mean p.a.	max. p.a.	min. p.a.
A. Togian	1°	4,7 cm	7,3 cm	1,0 cm	3,1 cm	9,4 cm	1,0 cm
	2°	10,3 „	14,6 „	4,2 „	6,3 „	10,4 „	2,1 „
Islands.	3°	14,6 „	40,6 „	1,0 „	5,0 „	9,4 „	1,0 „
B1. Gulf of	1°	4,2 „	11,0 „	1,0 „	5,4 „	13,0 „	1,0 „
Tomini,	2°	5,8 „	14,0 „	0,0 „	3,2 „	7,0 „	1,0 „
first part.	3°	9,0 „	28,0 „	1,0 „	3,6 „	8,0 „	2,0 „
B2. Gulf of	1°	3,5 „	7,0 „	0,8 „	2,3 „	3,9 „	0,8 „
Tomini,	2°	7,0 „	11,7 „	0,8 „	no sinking observed		
second part	3°	10,5 „	41,4 „	0,8 „	2,7 „	3,1 „	2,3 „
C. Kei	1°	1,7 „	2,0 „	1,4 „	3,7 „	6,8 „	0,7 „
	2°	1,4 „	1,4 „	1,4 „	4,1 „	4,7 „	3,4 „
Islands.	3°	5,5 „	14,9 „	2,0 „	2,7 „	2,7 „	2,7 „

Postscriptum by Dr. J. Verwey.

It is of much importance to know with certainty to what causes the "rising" and "sinking" of these reefs may be due. Are we dealing with growth in all cases where rising is stated, or may true rising of the bottom play a rôle? And where we see sinking: is it due to true sinking or have the corals died? — The distribution of the rising and sinking reefs shows that "rising" and "sinking" may occur in close neighbourhood of each other, so that real sinking of these reefs must be considered improbable. But moreover, it is a striking fact, that "sinking" of reefs is especially to be found near the surface,

where the influence of the surf is most important, whereas somewhat deeper it is of less importance; in the Togian Islands below 3 m hardly any sinking remains. This shows that increase of reef depth is caused by factors which influence coral growth and not by real sinking, as the latter would be the same near the surface and at greater depths. The same holds good for the rising of reefs; rising is of little importance near the surface, where the strong surf counteracts growth; it takes especially place in deeper water, where rising is of much more importance than sinking (compare the maximum for rising and sinking below 5 m!). So there can be little doubt that all rising is due to real upgrowth of the reef.

These observations, then, show, that in the Gulf of Tomini reefs below 5 m on the average grow upward as much as from 9 to 14.6 cm per year. The number of figures for the Kei Islands is too small to warrant the conclusion that their upgrowth below 5 m is not greater than 5.5 cm per year. Nevertheless it is probable that the average upgrowth of these reefs is smaller than that of the Tomini reefs. The figures for reef growth here found are high compared with those found in some other reef areas, where upgrowth has been considered to amount to 2.5 cm per year. But they agree well with figures which have been published on the growth rate of some branching corals.

KEI ISLANDS

133° E.

NOEHOE TJOET

ROA

6° S.
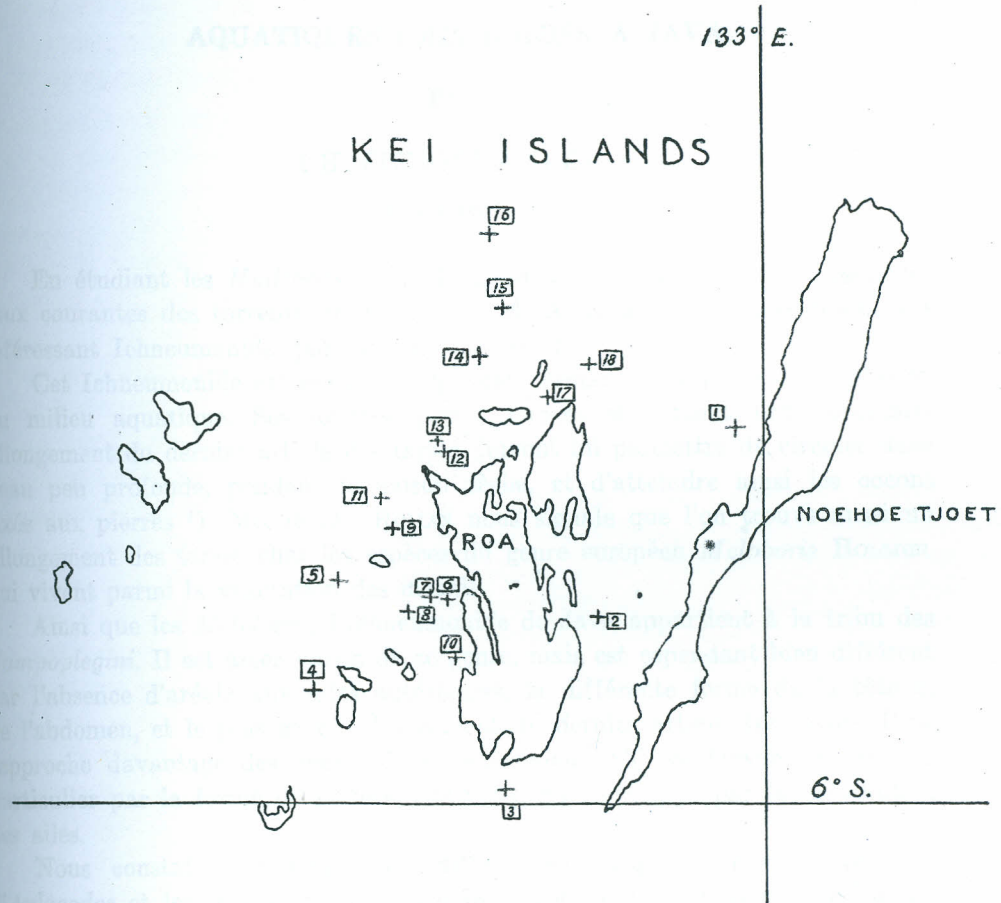
Kei Islands, scale 1:1.000.000; red +: rising; black +: sinking.