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GROWTH-RATE OF SAMOAN CORALS.

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By far the most accurate and extensive observations upon the growth-rate of corals are those of Vaughan, published in Year Book No. 14, Carnegie Institution of Washington (pp. 221–231). Vaughan studied the corals of Tortugas, Florida, and of Andros Island, Bahamas. He reared the planulæ of several species and weighed and measured other corals with their bases embedded in concrete attached to tiles, which were staked out with iron stakes upon the reef-flats, and he also observed the growth-rate of corals growing naturally upon the reefs. All of the forms studied by Vaughan were shallow-water species, such as constitute the reefs of the Florida-Bahama region. He found that, on the average, corals of the genus *Acropora*[1] made an annual growth of 54 mm. in diameter and 35 mm. in height; branched *Porites* 26 mm. in diameter and 19 mm. in height; while the massive *Porites astræoides* grows 13 mm. in diameter and 5 mm. in height per annum. In the Pacific, however, massive *Porites* heads constitute a more important element as reef-builders than in the Atlantic, and I find that these corals in Samoa and Fiji appear to make an annual average growth of 31 mm. in diameter and 17 mm. in height; thus, apparently growing more than twice as rapidly as the Atlantic species. In the Atlantic, *Orbicella annularis* is probably the dominant large, massive coral of the seaward slopes of the reefs, taking much the place that massive *Porites* does in the Pacific; but its growth-rate according to Vaughan is very slow, being on the average only about 7 mm. in diameter and 6 mm. in height. Thus a reef composed of the massive *Porites* of the Pacific might grow upward three times as fast as one composed of the Atlantic *Orbicella annularis*. Vaughan estimates that a reef composed of *Orbicella annularis* might attain a thickness of 150 feet in between 6,500 and 7,600 years, and according to my estimate such a reef composed of the massive *Porites* of Samoa might develop in 2,700 years; but neither of these corals grows at depths of 150 feet, so such a reef would have to start on talus, or on a structure built up by the very slow-building corals which grow at depths greater than 20 fathoms.

The older literature upon the rate of growth of corals is reviewed in Dana's *Corals and Coral Islands* (1872, pp. 123–127; 249–257), but it will be unnecessary to refer to it in detail, for the data it provides are not precise enough to warrant basing conclusion upon it respecting the growth-rate of corals; for in no single case is the actual growth-period of any of the measured specimens known. This objection also applies to the observations of A. Agassiz (1890, Bull. Museum Comparative Zoology at Harvard College, vol. 20, p. 61–53, 4 plates), upon three corals

[1] For the names of the Samoan corals I am indebted to Dr. T. Wayland Vaughan and Dr. J. Edward Hoffmeister. Vaughan has decided that the name *Acropora* should replace the term *Madrepora* of many authors. Hoffmeister's report on the corals collected and experimented upon by Mayor appears as Publication 343 of the Carnegie Institution of Washington.

that had grown upon a telegraph cable between Key West and Havana, which had remained under water 7 years and during the whole or a part of this time had been growing at depths of 6 to 7 fathoms, near Key West. Of two specimens of *Orbicella annularis* one had grown 2.5 and the other 2.25 inches above the cable; one specimen of *Mæandra areolata* had grown 1 inch, and a specimen of *Isophyllia dispsacea* 2.5 inches above the cable

In June 1890, Saville-Kent measured and photographed certain corals growing off Vivien Point, Thursday Island, Australia, and some of these were remeasured by me in November 1913. These measurements would indicate that a *Symphyllia* had grown at the average annual rate of 1.88 inches in diameter during 23 years, a massive *Porites* had grown 1.95 inches in diameter per annum; and a large *Goniastrea* had made no growth, but had survived in good condition during the 23 years. Thus this *Porites* at Thursday Island seems to have made an average annual gain in diameter of 49 mm., whereas my average for 17 heads of massive *Porites* in Samoa, some of which were observed for 3 successive years, is 31 mm. per annum. Possibly, however, the growth of *Porites* on the Great Barrier Reef is more rigorous than in Samoa. Heads 20 feet and more in diameter are not uncommon in Australia, whereas the largest head I could find in Samoa was 9.6 feet in diameter.

The most reliable study of growth-rate of Pacific corals which has hitherto been published is that of J. Stanley Gardiner, *Fauna and Geography of the Maldive and Laccadive Archipelagoes* (Cambridge University Press, vol. 1, pp. 327–333, 1903). Gardiner observed the size attained by young coral stocks which had grown in an artificial channel through the reef at Hululu, North Male Atoll, Maldives, which had been cleared of all coral 3 years previous to his study. He weighed, measured, ascertained the volume, specific gravity, and area in square centimeters covered by these corals, and presents his results in the form of a table and concludes that the average upward growth of these corals was 77 mm. in not more than 3 years, and that if broken down into a sheet they would form a layer of limestone 24.2 mm. thick. Thus these corals made an average upward growth of 25.6 mm. per annum. This is nearly in accord with the 24 mm. which is my calculated general average increase in height for the corals of Samoa. As Gardiner says, this growth might give rise to a reef about 14.5 fathoms in thickness in 1,000 years; while according to my estimate a reef 13.5 fathoms in thickness might be formed in this time. This slight difference has no meaning, due to the large factor of error in such estimates, but the apparent agreement in our results would indicate that the modern reefs now constituting the atolls and barriers of the Pacific could readily have grown upward to sea-level from the floors of submerged platforms since the close of the last glacial epoch.

The growth-rate of corals of Cocos-Keeling Atoll has been studied by F. Wood Jones and reported in his well-known book on *Coral and Atolls*, 1912, and also in a pamphlet upon the *Rate of Growth of the Reef-Building Corals*, published in London in 1908. Wood Jones finds that corals do not grow steadily, but by fits and starts, with no apparent reason for this activity or for its absence. This is amply confirmed by my studies in Samoa. For example, a massive *Porites* in Pago Pago Harbor grew 37 mm. in diameter in 1917–18, and then made no growth the following year; but in 1919-20 it again started to enlarge and amost made up its loss by growing 54 mm. in diameter in this last year. Wood Jones fastened copper bands to the stems of branching corals, the band being placed at a distance of 10 centimeters from the distal extremity. He then observed the growth made in 100 days and states that the average growth was 27.4 mm. in the 100 days, but unfortunately he tells nothing of what species of branching corals he studied, except that they were chiefly "Madrepores" (*Acropora*). In stating the growth-rate of massive forms he falls into error, for he states that such corals add 1/37 of their original circumference to their growth in 100 days, which amounts to practically one-tenth the circumference (or the diameter) in a year. Thus, according to Wood Jones a massive *Porites* 100 mm. in diameter would become 110 mm. in diameter at the end of a year, gaining 10 mm.; while a head 500 mm. in diameter would gain 50 mm. in the same time; or, as Wood Jones puts it, "a paradox is arrived at, for the older a coral is the faster it grows." This would indeed be a paradox were it true, but it is obviously untrue. For example, 8 massive *Porites* heads studied by me in Samoa had an average initial diameter of 339 mm. and made an average gain in diameter of 37.5 mm. per year; whereas 9 larger *Porites* heads having an average original diameter of 1,620 mm. made an average gain in diameter of 28 mm. per annum. In fact, the observations of Vaughan, as well as those made by me, indicate that young corals grow more rapidly than old ones and that in most and perhaps all species, after a certain size has been attained, growth practically ceases. Moreover, I find from studies made on *Porites clavaria* at Tortugas, Florida, that if a large coral which has ceased to grow, or is growing only slowly, be broken apart and its branches planted in concrete, these isolated branches continue to grow at the slow rate of the old stock and do not gain in growth-rate by being separated. The same is true if we girdle branches of old coral stocks of *Porites* by encircling them with a lethal mixture of corrosive sublimate and iodine, for then the tips of such physiologically isolated branches do not regain the growth-rate of young stocks, but still retain the reduced rate characteristic of senile corals. In fact, this "experiment" is often made in nature, for it is a common thing to find the hard part of a stem of *Acropora* or *Porites* girdled by sea-weed, millepora, or lithothamnium, and yet such a branch does not gain in growth-rate through being isolated from the stock.

But to return to the observations of Wood Jones, he states that his results are practically in accord with those of H. B. Guppy (1889, Scottish Geographical Magazine, vol. 5, pp. 573–575), who concludes that in the Cocos-Keeling Atoll massive forms of *Porites* grow upward between 12.7 and 19 mm. per year, while the branching *Porites* (*palmata?*) grows about 30 mm., and *Acropora* and certain forms of *Montipora* at least 100 to 125 mm. per year; and we may say that these figures would also apply quite well to the growth-rate of corals in the shallows of the reef-flats of Samoa.

Sluiter (1889, *Naturkundig Tijdschrift Nederland Indie*, Bd. 29, p. 375) found that a young reef, which grew up after the explosion at the Black Cliff of Krakatoa, had grown to a thickness of 200 mm. in not more than 5 years; but by contrast with this rapid growth J. Stanley Gardiner (1901, Proc. Cambridge Philosoph. Soc., vol. 11, part 3, pp. 214–219) calculates that corals in Fiji give an upward growth of only 5.19 mm. per annum, or a thickness of 17 feet in 1,000 years. In 1903, however, in speaking of the corals of the Maldive Islands, he says a reef might grow upward at least a fathom in 60 years.

It may be significant that even the lowest estimates of the rate of reef-growth would allow ample time for the rims of modern atolls to have grown upward to the surface since the close of the last glacial epoch, even if this growth necessitated the formation of a reef-wall 60 fathoms high, which may have formed while the melting of the ice gradually raised the level of the ocean to approximately that of modern times, although the actual change in sea-level since glacial times has probably not been more than 30 fathoms.

EXPERIMENTS AND OBSERVATIONS.

Seven sets of experiments were carried out upon the growth-rate of corals between 1917 and 1920.

One set of observations (table 2) was made upon photographed, weighed, and measured corals which were collected from the Aua reef-flat on the eastern side of Pago Pago Harbor. Figures 1 to 49, plates 2–14, illustrate these corals. After being marked by attaching numbered brass tags to these corals by means of copper wire, some of them were fastened to iron stakes driven into the reef-flat in quiet water 400 feet from shore, in a region wherein *Porites* flourishes. Other colonies had their basal stocks embedded in concrete 700 feet from shore in a region wherein *Acropora* is dominant and the water is agitated by the surge from the breakers. In this way 50 corals were treated and 38 of these survived and were found in July 1918. Observations upon corals growing naturally and undisturbed upon the reef-flats of Pago Pago showed that these weighed, photographed, and planted corals appeared to grow at a normal rate, due probably to the fact that the planted corals were removed from the water only long enough to photograph and weigh them, and were at once replaced upon the reef-flat.

Another set of observations, referred to in table 3 and figures 50 to 52, plate 15, were made upon 22 coral-heads growing naturally upon the reef-flats of Pago Pago Harbor. These were first measured in April 1917 and again in July 1918.

A third series consisted of 20 corals which were collected by means of a diving-hood at depths of 2 to 3 fathoms off the seaward edge of the Aua Reef in a region moderately agitated by breakers. A dense clustering of *Acropora* occurs in this place, at least three-quarters of the surface of the submarine slope being covered thickly with these corals. The corals were removed from the water only long enough to number, weigh, photograph, and embed their basal parts in concrete on tiles which were then replaced at a depth of 2.5 fathoms, close to the place where they were collected. These corals were numbered 32 D to 51 D, and the results of this experiment are recorded in table 4 and in figures 32 D to 51 D, plates 19–26.

Another set of observations was made upon 7 specimens of *Acropora* (*Tylopora*) *leptocyathus* Brook which were growing naturally on the breaker-washed edge of a reef-patch off Aua Village, Pago Pago Harbor. An idea of the appearance and association of these corals may be gained from plate IV, fig. B, and the results of the measurements and weighings are shown in table 5.

Two other series of observations were made upon massive *Porites* heads allied to *P. lutea* M. Ed. and H. and are recorded in tables 6 and 7 and illustrated by figure A of plate I which shows the appearance of 7 of the smaller heads which had been growing off Fagaalu Village, Pago Pago Harbor. The 9 larger heads which were growing naturally off Fagaalu and Utelei, Samoa, and Muaivuso, Fiji, are referred to in table 7.

In order to test the relative growth-rates of corals in the highly agitated shallow water of the upper surface of the reef-flat, and in deep, quiet water off the seaward edge of the reef, 24 corals of medium size from the upper surface of the Aua reef-flat were sawed into approximately equal halves. One-half marked S was embedded in concrete on the upper surface of a reef-patch off Aua, Pago Pago Harbor, in pure, highly agitated shallow water about 8 inches deep at lowest tides. The other half, marked D, was embedded in concrete on a tile and sunken to moderate depths off the edge of the same reef-patch on which the S series of corals was planted. Nos. 10 D to 12 D were grown from July 25, 1919, to June 12, 1920, in water 7 fathoms deep; Nos. 13 D to 24 D at a depth of 8.5 fathoms, and Nos. 25 D to 30 D at a depth of 5 fathoms. These sunken corals were in quiet water away from the surge of breakers and in a region in which we could detect no current by means of an Ekman meter. The bottom was covered with fine silt which clung like dust to every object and was at once fatal to all the *Acropora*. As none of these corals was in its natural environment, the water being either too agitated or too quiet, their growth-rates are not considered, but they are regarded merely as examples of the effects of agitation, or of stagnant water and silt, upon the growth-form of corals. The results are recorded in table 8 and are illustrated for the corals in pure, agitated, shallow water by figures 1 S to 24 S, and for the halves grown in deep, quiet, silted water by figures 1 D to 24 D, except that illustrations of the *Acropora* and others which died without growing are not shown. In general, the corals in agitated water produced short, thick-set stems, while those in the deep, quiet water developed long, slender stems. F. Wood Jones, in his *Coral and Atolls*, 1912, has well described these effects for *Pocillopora* and branched *Porites*, but our results show that *Psammocora*, *Pavona*, and even *Acropora* may also respond in a similar manner to these influences. Vaughan observed a similar response in an *Agaricea* grown in agitated water at Tortugas, Florida.

In order to determine the growth-rate of corals as affecting the development of the reefs, we must consider corals which die or do not grow as well as those which flourish, and take the average of the entire set of observations.

Some corals, such as the massive *Porites* and other huge heads, certainly live a century or more, but most of the species, such as the numerous *Acropora*, *Pocillopora*, and branched *Porites*, are short-lived and probably attain full growth in less than 10 years. Indeed, Vaughan showed that in *Favia fragum* of the Atlantic the growth is rapid during the first year, after which it declines, and in *Mæandra areolata* there is a decided falling off in growth-rate after the coral has attained a length of about 60 mm. Not one of the *Acroporas*, *Pocilloporas*, and branched *Porites* measured by Saville Kent in 1890 off Vivien Point, Thursday Island, Australia, could be found by me in 1913, and in Samoa it was evident that *Acroporas*, which had attained to large size and perfection of condition, generally the next year showed signs of deterioration and were more or less covered with sea-weed, millepores, bryozoa, or lithothamnium, and had made little growth. Thus, if we confine our measurements to small heads, we will probably get a rapid growth-rate, whereas large senile heads will give much less. The endeavor was therefore made to select specimens of average size over the Samoan reefs.

If a coral gains 9 mm. in diameter in 9 months it may be expected to attain 12 mm. in 12 months, the dimensions following a linear ratio proportionate to the time; but if we wished to calculate the *weight* at the end of the year the problem would be more complex. In hemispherical or oval massive heads, such as *Porites lutea*, *Symphyllia*, or *Goniastrea*, the weight may be expected to increase as the cube of the diameter. Thus if D be the diameter at the beginning of the year and if d be the increase in diameter due to a year's growth, then if D^3 represent the weight at the beginning of the year, $(D + d)^3$ will represent the weight at the end of the year. Often, however, these corals grow in very shallow water and are thus killed on top at low tide-level, so that they can grow only laterally as a ring of living polypites constituting the vertical outer margin of a cylinder, and in this case the weight gained per annum must be simply proportional to the relative diameters of the cylinder at the beginning and at the end of the year.

In most of the branching forms, such as *Porites andrewsi*, and the numerous species of *Acropora* and *Pocillopora*, the branches radiate outward from a basal center, and as the coral grows new branches develop from the sides of the old ones, so that the tips of the branches always remain approximately at a constant distance apart. In these cases one would expect the weight to increase as the square of the average linear dimension. Thus, if a coral of weight (w) has an average dimension of (d), where $d = \frac{(\text{length} + \text{breadth} + \text{height})}{3}$, and if this coral grows so that it attains a weight w and an average dimension of D, then

$$W = \frac{D^2 w}{d^2}$$

This formula would be strictly true if the branches all arose from the base and not at various levels from the sides of older branches, and if they were cylindrical and not tapering conically from base to tip. It seems, however, that these two factors about offset each other; for taking the average gain in weight in 15 months made by 6 branched *Acropora*, 4 *Porites*, 4 *Pocillopora*, and 1 *Pavona foliosa* of Samoa it was found that the observed average weight at the end of the 15 months was 1.09 times the expected average weight as calculated by the formula given above, the calculated and the observed gain in weight thus being practically identical. Thus, if we observe the gain in weight made in somewhat more or less

TABLE 1.—*Temperature, chlorine, salinity, and hydrogen-ion concentration of harbor-water and sea-water of Tutuila, Samoa.*

Date.	Place of observation.	Water temp.	Chlorine by $AgNO_3$ test.	Salinity.	P_H of sea-water.	Hydrogen-ion concentration.	Rainfall in 24 hours before observation.	Remarks.
1917		°C					*inches.*	
Mar. 12	Off mooring buoy No. B, Pago Pago Harbor.	29	....	....	8.185	0.652×10^{-8}	0.0	High tide.
18	....Do....	28.4	16.59	29.97	8.21	0.615×10^{-8}	3.2	Do.
15	Off Blacklock's Wharf, midway across harbor.	29	....	....	8.23	0.588×10^{-8}	0.1	Tide one-third high.
18	....Do....	28.4	17.6	31.80	8.2	0.63×10^{-8}	3.2	Rising.
12	Off Goat Island, Pago Pago Harbor, midway across harbor.	29	....	....	8.18	0.656×10^{-8}	0.0	High tide.
15	....Do....	29	19.04	34.4	8.23	0.588×10^{-8}	0.1	Tide rising, one-third high.
12	Mouth of Pago Pago Harbor, between Breaker Point and Double Point.	29	19.28	34.83	8.23	0.588×10^{-8}	0.0	High tide.
27	2.5 miles south of Breaker Point, off Pago Pago Harbor.	28.5	19.29	34.85	8.23	0.588×10^{-8}	1.2	Do.
29	In open ocean 0.25 mile south of Point Steps, the southernmost point of Tutuila.	28.3	19.23	34.83	8.23	0.588×10^{-8}	0.0	Nearly high tide.
28	In open ocean 0.25 mile east of Cape Matutula, the easternmost point of Tutuila, 10^h30^m a. m.	28.2	19.28	34.83	8.25	0.563×10^{-8}	0.0	Tide rising, nearly high.
Apr. 14	....Do., 3^h40^m p. m....	28.9	19.28	34.82	8.24	0.575×10^{-8}	2.0	Do.
July 12	....Do., 10 a. m....	....	19.3	34.87	....	....	0.0	
1920								
Mar. 28	Mangrove swamp at Massefau, upper part.	28.95	3.36	6.09	7.63	0.234×10^{-7}	0.1	Dark-colored swamps shut off from the sea by recent sand dunes.
28	Massefau, lower part of swamp near sea.	27.5	3.11	5.64	7.4	0.398×10^{-7}	0.1	
29	Mangrove swamp at Leone, Tutuila.	28.4	1.9	3.46	7.5	0.317×10^{-7}	0.0	
12	Off Pago Pago Village at inner end of Pago Pago Harbor.	29	18.025	32.56	8.18	0.660×10^{-8}	0.0	About 150 feet off mouth of large stream which enters harbor at Pago Pago Village. The live-car containing corals was placed here.
15	....Do....	29	18.99	34.31	8.23	0.588×10^{-8}	0.1	
20	....Do....	27.5	15.65	28.28	8.17	0.676×10^{-8}	3.4	
25	....Do....	27.9	16.66	30.10	8.2	0.630×10^{-8}	3.0	
31	....Do....	....	15.05	27.2	8.185	0.652×10^{-8}	1.0	
Apr. 2	....Do....	....	14.01	25.32	8.18	0.656×10^{-8}	0.3	
4	....Do....	30.9	17.37	31.38	8.18	0.656×10^{-8}	0.2	
6	....Do....	29.2	15.1	27.29	8.1	0.795×10^{-8}	0.2	
12	....Do....	24.8	0.502	0.93	7.33	0.831×10^{-7}	4.3	
13	....Do....	25.4	5.1	9.24	7.8	0.25×10^{-7}	0.2	
Mar. 6	Landing-stage of Blacklock's Wharf, inner part of Pago Pago Harbor.	29.8	....	....	7.75	0.3×10^{-7}	0.7	Low tide.
6	....Do....	28.2	....	....	8.05	0.890×10^{-7}	0.7	High tide.
8	....Do....	29	17.73	32.03	8.2	0.630×10^{-8}	1.3	Low tide.
11	....Do....	29.4	19.38	35.01	8.2	0.630×10^{-8}	0.0	Tide one-half high, rising.
13	....Do....	28.5	11.78	21.29	8.07	0.850×10^{-8}	0.2	Low tide.
16	....Do....	27.2	18.51	33.44	8.17	0.675×10^{-8}	0.1	Do.
16	....Do....	....	18.84	34.04	8.23	0.588×10^{-8}	0.1	High tide.
17	....Do....	27.2	18.51	33.44	8.17	0.676×10^{-8}	2.1	Low tide.
17	....Do....	27.6	18.535	33.48	8.14	0.725×10^{-8}	2.1	Rising, nearly high tide.
18	....Do....	25.4	13.42	24.25	8.1	0.795×10^{-8}	3.2	Nearly low tide, still ebbing.
19	....Do....	26.9	16.86	30.46	8.185	0.652×10^{-8}	7.8	Ebbing tide, nearly low.
Apr. 12	....Do....	26.6	8.58	15.52	8.0	$1. \times 10^{-8}$	4.3	Low tide.

than a year we can calculate the gain in a year with at least some degree of confidence.

In order to determine the growth-rate of the reef as a whole we must be careful to consider the relative abundance of the various kinds of corals. Thus in the most rapidly growing genus, *Acropora*, we find that in the shallows along the breaker-washed seaward edge of the reef *Acropora* (*Tylopora*) *leptocyathus* is the dominant coral, for its short, stout, conical stems, arising from a thick, expanded base clinging securely to the reef-floor, can resist the pounding of the surf as can no other species. This coral grows more slowly than any other *Acropora*, making an average gain of about 30 mm. in diameter per annum and very much less in height, attaining practically no upward growth after it has gained a height of 50 to 60 mm. This species is also an important element of the reef in deep, pure water off the seaward edge, where the surge of the sea produces considerable stirring of the water. (See fig. A of plate III.)

Another important element in reef formation in Samoa is *Acropora hyacinthus* (Dana), which is abundant over the shallows of the reef-flats in places somewhat protected from the breakers, but where there is considerable current and the water is free from silt. It is also a very important element of the seaward slope of the reef, its vase-shaped stocks covering wide areas, often to the exclusion of other forms. This coral grows rapidly, gaining about 100 mm. in diameter and 44 mm. in height per annum.

The third important element among the Samoan *Acropora* is seen in the forms well represented by *Acropora* (*Tylopora*) *samoensis* Brook, whose relatively long, nearly cylindrical stems radiate outward from a somewhat massive base. These forms grow almost as rapidly as *A. hyacinthus*, gaining about 89 mm. in diameter and 63 mm. in height per annum.

The fourth important element among the many acroporas is the tree-like form with branched and tapering conical stems, well exemplified by forms related to *A. cribripora*, *A. pulchra*, and *A. haimii*. The growth-rate of these forms is most rapid of all among *Acropora*, appearing to be on the average about 220 mm. in diameter and 120 mm. in height per annum in Samoa; and this appears to accord with Guppy's and Wood Jones's determinations of the growth-rate of related forms in the Cocos-Keeling Islands.

In estimating the increase in limestone due to growth of *Acropora* on the reefs, I would be inclined to give about equal weight to each of the four types described above. Thus, if all corals lived and grew normally, the growth-rate of *Acropora* as a whole over Samoan reefs would be about 110 mm. in diameter and 57 mm. in height, but due to the considerable death-rate and the poor growth of some individuals, my experiments recorded in the subsequent tables indicate that the effective rate is nearer 76 mm. in diameter and 30 mm. in height. This, however, gives no idea of the rapidity with which *Acropora* could build up a reef, for after death their fragile stems, unless coated with living lithothamnium, soon break and are scattered broadcast over the floor of the reef. On the seaward slope of the reef, however, under the surge of the breakers in depths of 1 to 6 fathoms

Acropora constitutes the determining element in the growth of the reef. These corals in this pure, agitated water grow most vigorously and develop stout, short, stumpy stems capable of resisting the force of the surges, thus making, according to my observations, only an average of about 19 mm. upward growth per annum, for corals do not readily raise their heads in regions where the surges are persistently tending to break them off. The average lateral growth is, however, 74 mm. per annum. This upward growth of 19 mm. is practically a permanent accession to the reef, for when they die these corals are thickly veneered with layer upon layer of lithothamnium, binding their tangled stems into a stout meshwork, into the interstices of which sand and loose fragments lodge to solidify the whole into permanent reef-rock.

Using a diving-hood, I have gone down on the seaward edge of the Aua Reef, when the lessening of the breakers would permit such action, and made a study of the relative abundance of the various genera of corals. I had hoped to be able to stake out areas 25 feet on the side and to count all corals within them, as was done on the shallow upper surface of the reef-flat, but the extreme irregularity of the surface made this impossible, and the difficulty was still further accentuated by the surges, which tended to throw one off one's feet, or into intricate caverns from which it might be difficult to escape. In the pure ocean-water, at depths of 1 to 6 fathoms under the breakers, the corals grow with a vigor unseen elsewhere. The individual stocks are many times larger than those of the same species growing in the shallow water on top of the reef-flat. Stocks of *Acropora hyacinthus* 3 feet in diameter are common, as are also branching *Acropora* covering 25 square feet in area. About three-fourths of the area of the seaward slope down to 4 to 6 fathoms off the Aua Reef is completely covered with coral-heads. The stems and stocks of these corals are stouter and of stronger build than those of corresponding species growing in the relatively quiet water of the shallows on top of the reef-flat. In strongly agitated water, corals thicken their stems and grow laterally rather than upward. Making use of a white board and a pencil tied to a string it was possible to take elaborate notes upon the reef conditions while one walked around among the coral-heads at depths down to about 6 fathoms. It was thus possible to count the number of heads of each species over definitely defined areas, and in this manner we found that off the seaward edge of the Aua Reef the coral-heads at depths of 2 fathoms and below consisted of 87 per cent *Acropora,* 10 per cent *Pocillopora,* and 3 per cent of all other forms, such as *Porites, Millepora, Alcyonaria,* etc. Thus the corals of the seaward slopes of the reefs of Tutuila consist chiefly of *Acropora,* the fastest growing of all corals.

Moreover, the overhanging seaward edge of the flat upper part of the reef is composed chiefly of *Acropora leptocyathus,* which, after it dies, remains bound to the reef by a veneer of lithothamnium. Beneath this overhanging edge there is a precipice or steep slope of from about 1 to 6 fathoms, at the base of which *Acropora* clusters thickly. Thus the reef grows seaward by the formation of an overhanging edge at low-tide level, which often breaks off and, falling to the bottom of the slope, aids in the upbuilding of the reef. Also at the bottom of the initial precipice, and down the seaward slope to depths of 6 to 7 fathoms, we find a dense growth of *Acropora* tending to build the reef upward and outward. Below 6 or 7 fathoms these corals become smaller and are farther apart, and the slope, which is about 30°, consists chiefly of dead coral which has rolled down from above, forming a talus.

There is doubtless a limit to the upward growth of the dense masses of *Acropora* which lie at the base of the reef precipice, for the breakers would destroy their stems should they approach too close to the surface. Thus the overhanging lithothamnium-veneered edge of the reef advances seaward at low-tide level, due chiefly to the growth of *Acropora leptocyathus*, which alone can withstand the full force of the breakers, and its fallen fragments serve to build up the wall to sea-level. Taking the average upward growth of the *Acropora* composing the seaward wall of the reefs of Tutuila to be 19 mm. per annum, and assuming that half of this (9 mm.) is effective, the reef might be expected to build itself upward 29.5 feet in 1,000 years, and this estimate is, I think, very conservative, for the remarkable growth of lithothamnium in the pure agitated water of the seaward slope of the reefs binds all dead coral into a firm network. I am inclined to believe, however, that due to this binding and veneering property of lithothamnium, which prevents the coral rock from decomposing after the death of the polypites, the entire 19 mm. per annum is effective in building up the reef, and thus an *Acropora* reef 10 fathoms thick might form in 1,000 years.

In silted regions *Porites* replaces *Acropora* to a considerable degree, so that in the Utelei side (western side) of Pago Pago Harbor branched *Porites*, massive *Porites*, and *Psammocora* are important elements in the formation of the seaward wall of the reef. Massive *Porites* in Samoa, according to my studies, makes an average upward growth of 17 mm. per annum, and this is a permanent accession to the reef. The branched *Porites* makes an upward growth of about 30 mm. per annum, but after death its stems break down unless veneered with lithothamnium, which does not grow readily in quiet water or in silted regions. It seems fairly safe, however, to say that a reef-wall composed of massive *Porites* might attain a thickness of 55 feet in 1,000 years, while a reef composed of branching *Porites* might grow upward at least 25 feet in the same period of time.

We are led to suspect that *Porites* is about as effective as *Acropora* as a reef-builder, from the fact that the reef on the eastern side of Pago Pago Harbor, which is predominantly *Acropora*, is no wider than that on the western side, which is largely *Porites*. Such estimates are of value only in that they indicate that the fringing reefs now surrounding Tutuila might readily have been formed since the close of the last glacial epoch. Our borings through the fringing reef in Pago Pago Harbor ran into hard basalt at a depth of 120 feet underlying the reef off Utelei, close to its seaward edge; 925 feet from shore. Another boring through the same reef 575 feet from shore ran into basalt at a depth of 121 feet, while 200 feet from shore the thickness of the reef down to its basaltic base was 68 feet. On the "Aua Line" of the Aua Reef, 512 feet from shore, hard basaltic rock was found at a depth of 156 feet. Thus at our most conservative estimate, the Utelei Reef might have been built up in 5,000 years. The following table gives the average annual growth-rate of Samoan corals according to my observations, recorded in tables 2 to 8, inclusive. In this estimate corals which died or made poor growth are given equal weight with those which throve well.

Annual growth-rate of Samoan corals.

Genus of coral.	Average size in mm. at beginning of year.		Gain in diam. or lateral growth in mm. per annum.	Gain in height in mm. per annum.	Average gain in weight in grams per annum.
	Diam.	Height.			
Acropora	80	60	76	30	501
Pocillopora	70	53	36	23	272
Branched Porites	92	62	44	30	222
Massive Porites	1,027	....	31	17	...
Pavona	117	68	39	32	34
Psammocora*	84	65	18	14	85
General average	....	....	41	24	...

*The colonies of *Psammocora* are so readily broken that this statement of growth is certainly less than that actually made.

In order to calculate the weight of dried stony matter, free from water or animal matter, which Samoan coral-heads of average size add to the reef-flats per annum, the weight of the living coral was ascertained both in 1917 and in 1918. Then in 1918 the coral was killed and its animal substance macerated or dissolved in KOH, after which the fresh water was largely abstracted by washing the skeleton in 90 per cent ethyl alcohol; the coral was then dried in the sun and weighed. This showed that the weight of the dried stony substance in various species of reef corals is on an average about 0.8 that of the same coral-head when alive. Various species of *Acropora* ranged from 0.07 to 0.9, while branched *Porites* were about 0.8, and large massive *Porites* slightly above 0.9.

Applying this correction, we find that on the Samoan Reef the gain in weight per annum of stony substance in various coral-heads of average size over the surface of the Aua reef-flat appears to be as follows: *Acropora*, 16 ounces; *Porites*, 7 ounces; *Pocillopora*, 9.5 ounces; *Pavona*, 12 ounces; *Psammocora*, 3 ounces avoirdupois. Knowing the number of coral-heads of these genera upon a reef-flat, we have a rough means of ascertaining the weight of limestone added to the reef each year by the growth of coral upon its upper surface.

By counting the numbers of coral-heads and species of corals on squares of 24 feet on the side (576 square feet), the squares being staked out from 50 to 100 feet apart from the shore to the seaward edge of the Aua reef-flat, we are led to the following conclusions:

On the upper surface of the Aua reef-flat between Breaker Point, Pago Pago Harbor, and the southern end of Aua Village, the area of the reef being 2,550,000 square feet, the numbers of corals are approximately as shown at top of page 65.

TABLE 2.—*Growth of corals on the reef-flat near the Aua Line, April 10, 1917, to July 10, 1918.*

No. of photograph and name of coral.	Description and remarks.	Dimensions, Apr. 10, 1917.	Weight of living coral Apr. 10, 1917.	Observed gain in dimensions in 15 months.	Observed gain in weight of living coral in 15 months.	Calculated gain in dimensions in 12 months.	Calculated gain in weight of dried stony substance in 12 months.	Calculated gain in weight of living coral in 12 months.
		millimeters.	*grams.*		*grams.*		*grams.*	*grams.*
1. *Acropora hyacinthus* (Dana).	Brown-purple with pink tips to branches. Branches delicate; found in water about 1 foot deep at low tide in region of breakers 790 feet from shore; planted at 700-foot station.	100.5 × 87 across top × 82 high.	....	274.5 × 214 × 49 height.	....	220 × 171 × 39 height.	....	....
2. *Porites andrewsi* Vaughan.	Brown-olive-colored branched *Porites* from about 600 feet from shore in water about 10 inches deep at low tide; grown at 400-foot station.	61.5 × 57 × 47.5 ...	28	53 × 52 × 60.5.....	269	42.5 × 42 × 48.5 .	167	215
3. *Porites andrewsi* Vaughan.	Brown-drab-colored branched coral from almost 600 feet from shore in water about 8 inches deep at low tide; grown at 400-foot station.	93 × 78 × 52.......	57	59 × 38 × 55	281	47 × 30.5 × 44...	156	232
4. *Porites andrewsi* Vaughan.	.....Do..................	125 × 98 × 80	198	51 × 36 × 25	268	41 × 29 × 20	179	215
5. *Pocillopora damicornis* var. *cespitosa* Dana.	Nos. 5, 6, and 7 were collected about 600 feet from shore in water about 8 inches deep at low tide and grown at 400-foot station.	55.5 × 54 × 40.5 ...	28.5	78.5 × 76 × 50.5 ...	347	63 × 61 × 40	211	264
6. *Pocillopora damicornis* var. *cespitosa* Dana.	.....Do..................	82 × 77 × 56.5.....	99	40 × 25 × 46.5.....	191	32 × 20 × 37	125	153
7. *Pocillopora damicornis* var. *cespitosa* Dana.	.....Do..................	84 × 71.5 × 62.....	269	108 × 95.5 × 76....	709	86.5 × 76.5 × 61 .	429	502
8. *Acropora hyacinthus* (Dana).	Nos. 8 and 9 grew side by side on one base of dead coral; they were purple-brown with pink tips to branches, found in rough water 700 feet from shore; planted at 700-foot station.	38 × 37 × 47	Nos. 8 and 9 combined 198.5.	91 × 36 × 53	Nos. 8 and 9 combined 737.	73 × 29 × 42	Nos. 8 and 9 combined 482.	595
9. *Acropora hyacinthus* (Dana).	.....Do..................	62.5 × 58.5 × 62 ...	....	147.5 × 88.5 × 37 ..	....	118 × 69 × 29.5..	....	....
11. *Acropora* aff. *A. humilis* (Dana).	Light-brown with violet tips; short blunt stems, found in breakers 790 feet from shore; grown in quiet water at 400-foot station; it barely survived; this coral does not live near shore, but thrives in rough water.	75 × 58.5 × 46.....	127.6	11 × 23.5 × 14.....	113	9 × 19 × 11	79	91
12. *Acropora (Tylopora) samoensis* (Brook).	Dark brown, thick stems; found 700 feet from shore in agitated water; grown at 700-foot station; damaged by forcible contact with a piece of dead *Acropora*, which it had practically overgrown.	82 × 83 × 84	141.7	90 × 22 × 71	....	72 × 17.5 × 57...	....	....
13. *Acropora (Tylopora) leptocyathus* (Brook).	Light brown, thick, short stems; taken from region of breakers where it thrives and grown at 700-foot station in a region of relatively quiet water, where it died and became covered with lithothamnium and bryozoa.	77.5 × 73 × 20, made very little growth before it died.	....	6.5 × 0 × 0........	....	....	....	....
14. *Acropora hyacinthus* (Dana).	Dark purple brown with pink tips to the slender stems; taken from rough water 750 feet from shore; grown at 700-foot station.	44.5 × 34.5 × 53 ...	....	134.5 × 138.5 × 114	....	108 × 111 × 91 ..	....	....

16. *Acropora* (*Tylopora*) *samoensis* (Brook).	Light brown, with stout, moderately short branches taken from agitated water 8 inches deep at lowest tide and 750 feet from shore, grown at 700-foot station.	87 × 82 × 65, with 20 main branches in 1917 and about 100 in 1918.	142	116 × 94 × 55	510	93 × 75 × 44	364	384
17. *Porites andrewsi* Vaughan.	Green color, slender branches; from quiet water 8 inches deep and 400 feet from shore; grown at 400-foot station.	123 × 96 × 68	284	61 × 72 × 9	553	50 × 57.5 × 7....	337	450
18. *Acropora* (*Polystachis*) *cymbicyathus* (Brook).	From rough water about a foot deep at low tide and 750 feet from shore, grown at 700-foot station.	227 × 177 × 80, nearly full grown in 1917; it made little growth by 1918.	....	12 × 21 × 5	....	10 × 17 × 4	....	....
19. *Acropora teres* (Verrill).	Brown stems; common on reef-flats in region wherein surges die out in ordinary weather; taken from about 680 feet from shore in water about a foot deep at low tide; grown at 700-foot station.	85.5 × 60 × 68; in 1917 it had about 13 main and about 10 short side branches; in 1918 it had more than than 257 branches.	57	338.5 × 331 × 166..	1985	271 × 265 × 133 .	1,113	1383
20. *Favites abdita* (Ellis and Sol.)	Light olive-brown with vivid green centers to polypites; found about 650 feet from shore and grown at 700-foot station; specimen incrusting a dead acropora.	83 × 52...........	....	24 × 35	....	19 × 28..........	....	....
22. *Acropora* (*Tylopora*) *leptocyathus* (Brook).	Light brown, short, thick-stemmed, acropora from region of breakers, where it thrives; grown at 700-foot station, where it did not flourish.	117 × 116 × 48	241	43 × 26 × 5	354	34.4 × 21 × 4....	227	284
23. *Pavona decussata* Dana.	From about 500 feet from shore in quiet water about 8 inches deep at low tide in a region where this coral flourishes; grown at 400-foot station.	105 × 91 × 64	312	47 × 34 × 41	347	38 × 27 × 33	238	278
24. *Acropora vanderhorsti*, Hoffmeister.	Long-stemmed, stout-branched, brown-colored acropora from 650 feet from shore in water about 14 inches deep at lowest tide; grown at 700-foot station.	110 × 123 × 84; in 1917 it had 10 main branches, the longest 84 mm.; in 1918 it had 47 branches, the longest 160 mm.	85	136 × 141 × 106 ...	355	109 × 113 × 85 ..	215	268
28. *Pocillopora damicornis cespitosa* Danas (*brevicornis* facies.)	Massive short-stemmed pocillopora from rough water 750 feet from shore; grown in quiet water at 400-foot station, where it did not thrive.	108.5 × 68 × 52....	326	36.5 × 40 × 32.....	149	29 × 32 × 25	78	91
29. *Acropora corymbosa* (Lamarck).	Brown stems with pink tips; from water about 8 inches deep at low tide 600 feet from shore; grown at 400-foot station; this coral thrives in quiet water about 600 feet from shore.	66 × 63 × 55	284	53 × 59 × 37	397	42.5 × 47 × 30...	228	278
30. *Pocillopora eydouxi* M. E. and H.	Pink-colored, stout, short-stemmed coral growing in rough water; taken from region of breakers 780 feet from shore and grown at 700-foot station, where it thrives well.	104.5 × 60.5 × 57 ..	....	23.5 × 24.5 × 59 ...	....	19 × 20 × 47	....	....
32. *Acropora* (*Tylopora*) *leptocyathus* (Brook).	Light brown with short, stout stems from region of breakers where it thrives; grown 700 feet from shore in relatively quiet waters, where it soon died.	108 × 94.5 × 51....	....	13 × 4.5 × 0.......	....	10 × 4 × 0	....	....

TABLE 2.—*Growth of corals on the reef-flat near the Aua Line, April 10, 1917, to July 10, 1918.*—Continued.

No. of photograph and name of coral.	Description and remarks.	Dimensions, Apr. 10, 1917.	Weight of living coral Apr. 10, 1917.	Observed gain in dimensions in 15 months.	Observed gain in weight of living coral in 15 months.	Calculated gain in dimensions in 12 months.	Calculated gain in weight of dried stony substance in 12 months.	Calculated gain in weight of living coral in 12 months.
33. *Acropora* (*Conocyathus*) *valida* (Dana).	Brown stems with pink tips from region of breakers in water 1 foot deep at low tide; grown at 700-foot station.	154 × 130 × 79		70 × 76 × 16		56 × 61 × 13		
34. *Acropora hyacinthus* (Dana).	Brown stems with pink tips; from water 10 inches deep at low tide, 750 feet from shore.	67 × 45 × 80	85	223 × 135 × 57	992	178 × 108 × 46	564	723
35. *Acropora* (*Tylopora*) *leptocyathus* (Brook).	Light brown, short, thick stems, from breakers about 800 feet from shore; grown at 700-foot station, where it did not thrive.	107 × 90 × 29		15 × 17 × 11		12 × 14 × 9		
36. *Leptastrea purpurea* (Dana).	From about 550 feet from shore in quiet water; grown at 700-foot station; it was three-fourths dead in 1918 and had made no growth.	38 × 27 × 24	128	0				
37. *Porites* aff. *P. lutea* M. Edw. and H.	3 small colonies of massive points; probably detached from a larger head; grown at 400-foot station.	Largest 77 × 48 × 25; medium size 28 × 22; smallest 12 × 10.		Largest 14 × 14 × 20; medium 6 × 1 smallest 8 × 7.		Largest 11 × 11 × 16; medium 5 × 0.8; smallest 6.5 × 6.		
38. *Acropora* aff. *formosa* var. *gracilis* (Dana).	Long branches, light brown with violet tips; from water about 2 feet deep, 600 feet from shore, grown at 400-foot station; only 1 of the 6 original branches lived, but this one made a good growth.	6 branches, longest 56 mm., shortest 26 mm. long.	42.5	8 main and about 132 terminal branches; branches had grown about 231 mm. in length; dimensions of stock in 1918, 298 × 241 wide × 287 high.	383	Growth of branches 185 mm. in length, in 12 months.	249	306
39. *Psammocora contigua* var. *maldivensis* Gardiner.	Dark olive-brown with very fragile stems, living only in quiet water; taken from about 400 feet from shore; grown at 400-foot station.	85 × 76.5 × 55	100	21 × 23.5 × 18	128	17 × 19 × 14	79	102
40. *Psammocora contigua* var. *maldivensis* Gardiner.	Do. Specimen badly broken in 1918	127.5 × 100 × 82.5	198	28.5 × 44 × 3.5 badly broken.	43			
41. *Psammocora contigua* var. *maldivensis* Gardiner.	Do. Very badly broken in 1918	81 × 62 × 52	71	3 × 19 × 0				
48. *Galaxea fascicularis* (Linn.).	From a crevice in region of breakers 760 feet from shore, grown at 700-foot station.	109 × 71 × 40 nearly full grown.	397	7.5 × 5 × 5	29	6 × 4 × 4	17	23
49. *Pavona frondifera* Lamarck.	Fragile, foliated, light brown *Pavona* common 450 feet from shore, where it was found in water 10 inches deep at low tide; grown at 400-foot station.	135 × 126 × 71.5	765	73 × 15 × 18.5	539	58.5 × 12 × 15	317	431

About 502,200 heads of *Porites* grow over 72 per cent of the area of the upper surface of the reef-flat and contribute (due to their growth) 246,000 pounds of limestone per annum.

347,500 *Acropora* distributed over 56 per cent of the reef-flat contribute annuly 465,400 pounds of limestone.

57,600 heads of *Pocillopora* scattered over the entire reef-flat contribute 30,300 pounds of limestone.

55,900 *Psammocora* distributed over 30 per cent of the reef-flat contribute each year 11,000 pounds of limestone.

15,500 *Pavona* found over 35 per cent of the reef-flat contribute each year about 11,600 pounds of limestone.

Thus the growth of these corals appears to add about 764,300 pounds of limestone each year to the upper surface of the reef-flat, this limestone being estimated as dried and free from animal matter; and as these genera contribute 95 per cent of the entire coral-heads of the reef-flat, it is probable that about 800,000 pounds of limestone are added to the reef-flat each year by the growth of the corals over its surface, or about 2.8 pounds per square yard; or, taking the specific gravity of limestone as 1.8, this would be equivalent to a layer of coral about 8 mm. in thickness per annum over the entire reef flat; and as we have shown in the paper upon *Causes which tend to Maintain a Constant Depth over Pacific Fringing Reef-flats*, this is about the amount the reef is degraded each year.

The corals of Samoa are more effective as reef builders than are those of the Atlantic according to Vaughan. The massive *Porites* of Samoa which takes the place of *Orbicella annularis* of the Atlantic grows upward about 17 mm. per annum instead of 6 to 7 mm., as does the Atlantic *Orbicella*. Moreover, one never sees in the Atlantic anything like the dense clustering of vigorous stocks of *Acropora*, such as characterize the seaward slopes of the Samoan reefs. A far greater proportion of the ground is covered by corals in Samoa than on the Atlantic reefs, and while the growth-rate of Samoan *Acropora* is only slightly greater than that of the Atlantic species according to Vaughan, yet the far greater abundance of this genus over the Samoan reefs causes it to be more effective as a reef builder than are the Atlantic *Acropora*. In middle Oligocene times the Atlantic reefs were probably comparable with those of the modern Pacific, but the Atlantic reefs have been impoverished by the dying out of many forms which still survive in the Pacific.

Table 2 shows the growth of corals on the Aua reef-flat near the "Aua Line," east side of Pago Pago Harbor, Samoa, from April 10, 1917, to July 10, 1918. These corals were photographed, weighed, measured, and marked with serially numbered yellow metal tags attached to the corals by copper wire. The photographs bear numbers corresponding to those on the metal tags. Nos. 2 to 7, 11, 17, 23, 28, 29, 37 to 39, 40, 41, and 49 were attached by iron wires to iron stakes driven into the reef-flat 400 feet from shore, in quiet water 9 inches deep at low tide. The basal parts of Nos. 1, 8, 9, 12 to 14, 16, 18 to 20, 22, 24, 30, 32 to 36, and 48 were embedded in concrete near the outer edge of the Aua reef-flat 700 feet from shore in agitated water about 18 inches deep at low tide in a region wherein the breakers just die out in ordinary weather.

In 1918, the animal matter was removed by maceration and then the corals were soaked in KOH, which was removed by 90 per cent ethyl alcohol, after which the

TABLE 3.—*Gain per annum in linear dimensions of corals growing naturally in Pago Pago Harbor, Tutuila, Samoa, 1917 to 1918.*

Locality.	Description and name of coral.	Dimensions in millimeters.	Observed gain.	Gain per annum.
			millimeters.	*millimeters.*
Near shore off some large black lava rocks at Double Point, Pago Pago Harbor, exposed to the full force of the breakers at the western side of the harbor entrance. Bottom hard, broken, and rocky without sand or silt. Water constantly agitated and about a foot deep at lowest tides.	Brown colored *Acropora* (*Tylopora*) *leptocyathus* (Brook). This species thrives in the breakers.	July 5, 1918; 342 × 305 × 50 high.... Mar. 1, 1917; 249 × 184 × 4 high...	93 × 121 × 10 high..	70 × 90.7 × 7.5 high.
Do...........................	*Acropora*..............	July 5, 1918; 148 × 121 × 66 high... Mar. 10, 1917; 47.5 × 42.5 × 35.5 high	100.5 × 78.5 × 30.5 high..............	75 × 59 × 23 high.
Do...........................	*Acropora syringodes* (Brook) Fig. 51	July 5, 1918; 266 × 188 × 111 high.. Mar. 10, 1917; 80 × 53 × 32 high...	186 × 135 × 79 high.	139.5 × 101 × 59 high.
Do...........................	*Pocillopora damicornis* var. *cespitosa* Dana.	July 5, 1918; 187 × 169 × 71 high... Mar. 10, 1917; 149 × 105 × 62 high.	38 × 64 × 9 high....	28.5 × 48 × 7 high.
Do...........................	*Pocillopora damicornis* var. *cespitosa* Dana.	July 5, 1918; 192 × 133 × 75 high... Mar. 10, 1917; 99 × 79 × 58 high...	93 × 54 × 17 high...	70 × 40.5 × 13 high.
Do...........................	*Pocillopora damicornis* var. *cespitosa* Dana.	July 1918; 147 × 152 × 71 high..... March 1917; 53 × 52 × 24 high.....	94 × 100 × 47 high..	70.5 × 75 × 35 high.
Do...........................	*Pocillopora damicornis* var. *cespitosa* Dana.	July 1918; 123 × 59 × 59......... March 1917; 38 × 34.5 × 21.........	85 × 24.5 × 38 high..	64 × 18 × 28.5 high.
On the rocky floor of the reef-flat off Aua Village, about 440 feet from shore on the eastern side of Pago Pago Harbor in quiet water about 8 inches deep at lowest tides.	Massive, dome-shaped, olive-colored *Porites* aff. *P. lutea* M. Edw. and H. Fig. 52).	July 12, 1918; Circum. 52.5 inches.... April 6, 1917; Circum. 45.5 inches....	Gain in circumference 5.6 inches (142.2 mm.)	Gain in diameter per annum, 45 mm.
Do...........................	*Pavona decussata* Dana...	July 12, 1918; 271 × 257 × 194 high. Apr. 6, 1917; 205 × 210 × 147 high..	66 × 47 × 47 high...	53 × 38 × 38 high.
Do...........................	*Pavona decussata* Dana...	July 12, 1918; 292 × 232 × 196 high. Apr. 6, 1917; 241 × 178 × 136 high.	51 × 54 × 60 high...	37 × 40.5 × 45 high.
Aua reef-flat eastern side of Pago Pago Harbor, 600 feet from shore in water about 10 inches deep at lowest tides; bottom hard, broken coral with a little coarse sand; region is fairly quiet; water beyond the usual wash of the breakers.	*Favites abdita* (Ell. and Sol.).	July 17, 1918; 224 × 167 × 74 high.. Mar. 24, 1917; 183 × 151 × 46 high.	41 × 16 × 28 high...	31 × 12 × 21 high.
Do...........................	*Leptastrea purpurea* (Dana), flat-incrusting colony.	July 19, 1918; 41 × 41............. March 24, 1917; 34 × 34...........	7 × 7..............	5 × 5
Do...........................	*Pavona decussata* Dana...	July 18, 1918; 145 × 276 ocean top... Mar. 24, 1917; 130 × 249 ocean top.	15 × 27 across top....	11 × 20 across top.
Do...........................	Nodular *Millepora*.......	July 22, 1918; 117 × 72 × 30 high... Mar. 24, 1917; 86 × 49 × 23 high...	31 × 23 × 7 high....	23 × 17 × 5
Corals growing on rocks on the Aua reef-flat, eastern side of Pago Pago Harbor, 750 feet from shore, just shoreward of the inner wash of the breakers, in water about a foot deep at lowest tides.	*Pocillopora damicornis* var. *cespitosa* Dana.	Aug. 4, 1918; 183 × 123 × 79 high... Apr. 12, 1917; 149× 8.15 × 49 high...	34 × 41.5 × 30 high.	25.5 × 31 × 22.5
Do...........................	*Porites andrewsi* Vaughan, gray-green in color.	Aug. 4, 1918; 173 × 217 × 144 high.. Apr. 12, 1917; 142 × 118 × 106 high.	31 × 99 × 38 high...	23 × 74 × 28.5
Do...........................	*Acropora samoensis* (Brook). brown with yellow tips.	Aug. 4, 1918; 251 × 164 × 69 high.. Apr. 17, 1917; 162 × 120 × 53 high.	99 × 24 × 16........	74 × 18 × 12
Do...........................	*Acropora damicornis* var. *gracilis* (Dana). Delicate branches, light brown with blue tips.	Aug. 4, 1918; 154 × 184 × 72....... Apr. 17, 1917; 154 × 118 × 46...... Cut off from lateral growth by crowding in a crevice.	0 × 66 × 26.........	2 × 49.5 × 19.5
Do...........................	*Acropora teres* (Verrill). Olive-brown branches with blue-violet tips.	Aug. 4, 1918; 510 × 445 × 195 high. Apr. 17, 1917; 264 × 178 × 190 high. Prevented from growing upward by low-tide level.	246 × 267 × 5.......	184 × 200 × 4
Do...........................	*Acropora teres* (Verrill)....	Aug. 4, 1918; 538 × 434 × 125 high. Apr. 17, 1917; 267 × 190 × 60 high..	271 × 244 × 65 high.	203 × 183 × 49 high.
Growing upon the vertical side of a large black lava rock about 200 feet from shore on the Aua reef-flat eastern side of Pago Pago Harbor; coral just under water at lowest tides.	*Acropora corymbosa* (Lamarck). Fig. 50.	July 17, 1918; 179 × 171 × 116 high. Apr. 9, 1917; 115 × 126 × 76.5 high.	64 × 45 × 39.5 high..	48.5 × 34 × 30 high.
Grown at a depth of 5 fathoms in Pago Pago Harbor in quiet silted water.	*Fungia* sp..............	July 6, 1920; 86 × 77 × 16......... Aug. 19, 1919; 70 × 61 × 13........ The weight changed from 64 to 85 grams; a gain of 21 grams.	16 × 16 × 3 mm..... Gain in weight 21 grams.	17 × 17 × 3

coral was dried in the sun and then weighed, in order to determine the weight of the stony substance, freed from animal matter and water. This method provided the means for calculating the weight of the stony substance as it was in 1917. The dimensions are stated in millimeters, the height being given last. Thus 10×20×15, means 10 × 20 mm. across the top × 15 mm. high.

These corals were collected at a depth of 1 to 2 fathoms on a bottom thickly covered with living coral in pure, agitated water, off the seaward edge of the reef on the eastern side of Pago Pago Harbor off Lepua Village. These corals were photographed, weighed, and measured and their bases set in concrete on concrete tiles which were secured by heavy spikes to the rocky bottom about 2

TABLE 4.—*Corals collected off Lepua Village, Pago Pago Harbor.*

Photo No., description, and name.	Dimensions on May 29, 1920, and on Sept. 3, 1919, in millimeters.	Weight on May 29, 1920, and Sept. 3, 1919.	Gain in dimensions in 9 months.	Gain in weight in 9 months.	Calculated gain in dimensions in one year.
		grams.	*millimeters.*	*grams.*	*millimeters.*
32 D. Brown - colored *Acropora hyacinthus* (Dana).	May 29, 1920; 176 × 138 × 136 high Sept. 3, 1919; 113.5 × 110 × 109 high.	May 1920; 850 Sept. 1919; 680	52.5 × 28 × 27 high.	170	70 × 37 × 33 high.
33 D. Greenish - brown, coarse-branched, *Pocillopora eydouxi* M. Ed. and Haime.	1920; 103 × 82 × 115............ 1919; 76.5 × 56 × 106...........	1920; 326 1919; 191	26.5 × 26 × 9.	135	35 × 34 × 12
35 D. Brown - colored *Acropora hyacinthus* (Dana) with pinktips to the branches.	1920; 247 × 214 × 99............ 1919; 116 × 119 × 88............	1920; 1,162 1919; 496	131 × 95 × 11.	666	174 × 126 × 16
36 D. *Acropora cymbicyathus* (Brook). Brown-colored *Acropora*.	1920; 199 × 168 × 90............ 1919; 180 × 106 × 84............	1920; 652 1919; 447	19 × 62 × 6...	205	25 × 82 × 8
40 D. *Millepora truncata* Dana. Olive - brown *Millepora* with greenish-yellow tips to its coarse branches.	1920; 107 × 49 × 135............ 1919; 94 × 33 × 134.............	1920; 468 1919; 439	13 × 16 × 1...	29	17 × 21 × 1
41 D. *Coscinarea columna* (Dana)	1920; 57 × 82 × 110............. 1919; 55 × 84 × 97..............	1920; 503 1919; 453	2 × – 2 × 13.	50	3 × – 3 × 17
42 D. *Pocillopora eydouxi* M. E. and H. Coarse-branched, greenish-brown *Pocillopora*.	1920; 153 × 115 × 124........... 1919; 136 × 87 × 126............	1920; 836 1919; 574	17 × 28 × –[1].	262	23 × 37 × –[1]
43 D. Light-brown, fine-branched *Acropora*.	1920; 166 × 148 × 121........... 1919; 113 × 87 × 115............	1920; 489 1919; 213	53 × 61 × 6...	276	70 × 81 × 8
44 D. Olive - brown *Millepora* with yellow-green tips. *Millepora truncata* Dana.	1920; 49 × 31 × 95.............. 1919; 45.5 × 30 × 94............	1920; 218 1919; 205	3.5 × 1 × 1...	13	5 × 1 × 1
45 D. *Pocillopora damicornis* var. *cespitosa* Dana (*brevicornis* facies). Dark-brown *Pocillopora*.	1920; 110 × 141 × 82............ 1919; 87 × 116 × 73.............	1920; 340 1919; 241	23 × 25 × 9...	99	31 × 33 × 12
47 D. *Acropora tutuilensis*, Hoffmeister. Brownish-green, coarse, long-branched.	1920; 204 × 112 × 160........... 1919; 138 × 34 × 151............	1920; 369 1919; 170	66 × 78 × 9...	199	88 × 104 × 12
49 D. *Pocillopora brevicornis* Lamarck. Olive-brown.	1920; 113 × 104 × 73............ 1919; 94.5 × 87.5 × 57..........	1920; 311 1919; 240	18.5 × 16.5 × 16	71	25 × 22 × 21
50 D. Brown - colored. *Acropora hyacinthus* (Dana).	1920; 128 × 178 × 97............ 1919; 72 × 109 × 78.............	1920; 219 1919; 128.	56 × 69 × 19..	91	74 × 92 × 25
51 D. *Acropora valida* (Dana). Brown - colored, short-branched.	1920; 111 × 120 × 98............ 1921; 74 × 79 × 63.5............	1920; 220 1919; 50	37 × 41 × 34.5.	170	49 × 55 × 46

fathoms deep, near the place wherein the corals were collected, in order to withstand the heavy surge of the breakers over them.

The average dimensions of these seven corals on July 27, 1919, were 109 × 119 × 43 mm. high, and it was found that specimens of this size weigh 461 grams. These corals were remeasured and weighed on June 3, 1920, and found to have gained on the average 91 grams in weight. These corals were of about average size for their species when growing on the edges of reefs.

TABLE 5.—*Growth-rate of seven specimens of Acropora (Tylopora) leptocyathus (Brook) growing naturally on breaker-washed edge of a reef patch off Aua Village, Pago Pago Harbor, Samoa.*

Remarks.	Dimensions, July 27, 1919 and June 3, 1920, in millimeters.	Observed gain in dimensions between July 27, 1919, and June 3, 1920.	Weight, June 3, 1920.	Calculated increase in dimensions in one year.
		millimeters.	*grams.*	*millimeters.*
About one-third dead in 1920...	1920: 104 × 103 × 45 high 1919: 82 × 84 × 53 high	22 × 19 × 8 high	539	26 × 23 × 8 high
Alive and flourishing, 1920......	1920: 175 × 150 × 48..... 1919: 137 × 135 × 48.....	38 × 15 × 0......	964	46 × 18 × 0
Dead, 1920..................	1920: 97 × 94 × 46..... 1919: 90 × 90 × 46.....	7 × 4 × 0......	240	8 × 5 × 0
Alive, 1920..................	1920: 199 × 156 × 41..... 1919: 148 × 126 × 40.....	51 × 30 × 1......	482	61 × 36 × 1
Dead on one side, 1920.........	1920: 124 × 99 × 33..... 1919: 109 × 92 × 33.....	15 × 7 × 0......	666	18 × 8 × 0
Alive, 1920..................	1920: 181 × 157 × 40..... 1919: 124 × 118 × 35.....	57 × 39 × 5......	822	68 × 47 × 6
Alive, 1920..................	1920: 174 × 146 × 46..... 1919: 145 × 120 × 46.....	29 × 26 × 0......	893	35 × 31 × 0
	Average dimensions in 1919, 119 × 109 × 43 mm. high. Average in 1920, 151 × 129 × 43.	Average gain in dimensions from July 27, 1919, to June 3, 1920, 32 × 20 × 0 mm.	Average weight on June 3, 1920, 658 grams.	Average gain in one year, 36 × 24 × 0 mm.

These corals grew about 400 feet from shore in water about a foot deep at lowest tide. They were weighed (ounces avoirdupois) and measured on August 1, 1918, and then each coral was fastened by an iron spike to the rocky floor of the reef-flat, the spikes being driven through the dead central area of the coral-head. (See figure A, plate I.) Two small galvanized-iron nails were driven into the sides of each coral to mark a diameter. The corals were weighed with these side-nails in place but without the central spike. Massive *Porites* heads flourish in the region in which these corals were grown, and all were collected within a few feet of the place wherein they were grown from August 1, 1918, to August 23, 1919.

The coral-heads described in table 7 grew in quiet water about 1 to 4 feet deep at lowest tide. They were dead about at low-tide level and were growing laterally. They were from 150 to 360 feet from shore. At Fagaalu and Muaivuso the bottom was covered with calcareous sand and the corals grew above it, but at Utelei the bottom is rocky. These corals are in protected places away from the breakers.

Table 8 describes corals collected on the Aua Reef-flat. Each coral was sawed into two approximately equal halves marked "S" and "D." One of these

TABLE 6.—*Growth of massive Porites heads allied to P. lutea M. Edw. and H., from off Fagaalu, on the west side of Pago Pago Harbor, Samoa.*

Date.	Circumference.	Diameters.	Weight.	Observed gain.			Calculated annual growth.		
				Gain in circumference.	Average gain in diameter.	Gain in weight, oz. avoirdupois.	Circumference.	Diameter.	Weight.
	mm.	*mm.*	*ounces.*	*mm.*	*mm.*		*mm.*	*mm.*	*ounces.*
Aug. 1, 1918....	870	270 × 276	326	90	36	114	85	34	107
Aug. 23, 1919....	960	306 × 313	440						
Aug. 1, 1918....	902	276	226	132	35	130	124	33	122
Aug. 23, 1919....	1,034	311	356						
Aug. 1, 1918....	1,448	472 × 425	....	105	40	....	99	38	....
Aug. 23, 1919....	1,553	509 × 469	....						
Aug. 1, 1918....	....	88 × 62	....	....	38	....	....	36	....
Aug. 23, 1919....	....	126 × 101	....						
Aug. 1, 1918....	1,400	431 × 435	....	70	44	....	66	41	....
Aug. 23, 1919....	1,470	477 × 477	....						
Aug. 1, 1918....	629	174 × 216	106	86	45	94	81	42	89
Aug. 23, 1919....	715	215 × 256	200						
Aug. 1, 1911....	1,130	360 × 355	334	96	35	146	90	33	85
Aug. 23, 1919....	1,226	391 × 393	480						
Apr. 16, 1917....	648	....	168	171	....	85	137	43	78
July 8, 1918....	819	....	274						

Average initial circumference, 1,068 mm.; average initial diameter, 339 mm.; average gain in diameter in 12 months, 37.5 mm.; average gain in weight in 12 months, 96 oz. av. or 2,722 grams.

halves marked "S" was embedded in concrete and kept from July 25, 1919, to June 12, 1920, in constantly agitated pure water, in a tide-pool near the seaward margin of a reef-patch off Aua Village, Pago Pago Harbor. The water in this tide-pool was about a foot deep at low tide and was constantly in motion, due to the surge of the sea. The other half of each coral, marked "D," was embedded in concrete on a concrete base, and lowered into quiet water off the northern edge of the same reef-patch. Nos. 1 D to 12 D were grown in water 7 fathoms deep, and Nos. 13 D to 24 D in water 8.5 fathoms deep The bottom was hard and rocky and no current could be detected by an Ekman meter in this deep water. Thus one half, "S," of each coral was grown in shallow, agitated water, while the other half, "D," was grown in quiet, deep water. The reef-patch upon which and off which this experiment was made is off Aua Village and is marked "uncov. at L. W." on U. S. Hydrographic Chart No. 2563 of Pago Pago Harbor.

All of the *Acropora* placed in deep water were killed at once by the silt. The *Porites*, *Psammocora*, *Pocillopora*, and *Pavona* generally survived in the quiet deep water, but usually produced abnormally slender stems, whereas the halves of the corals grown in the agitated shallow water usually produced short, thick, compact stems.

The *Acropora leptocyathus* grown in shallow agitated water was in its natural habitat, but all other corals were in abnormal habitats.

TABLE 7.—*Annual gain in diameter of large, flat-topped, massive Porites heads (allied to P. lutea M. Edw. and H., growing on the shallow reef-flats off Fagaalu and Utelei, on the west side of Pago Pago Harbor, Samoa, and off Muaivuso Village, Viti Levu, Fiji.*

Description of the *Porites* head.	Gain in diameter in 12 months.
An elliptical *Porites* about 150 feet from shore off Utelei Village. Dimensions in millimeters Apr. 16, 1917: circumference 3,395 mm., diameters 951 × 1,134 mm.	49 mm. in 1917–1918 33 mm. in 1918–1919 Dead, 1920, turned over on side.
Nearly circular, isolated, flat-topped *Porites* about 200 feet from shore of Utelei. Dimensions in millimeters, Apr. 16, 1917: circumference 3,054 mm., diameter 972 mm.	18 mm. in 1917–1918 43 mm. in 1918–1919 6 mm. in 1919–1920
Oval *Porites* about 300 feet from shore off Utelei. Dimensions on Apr. 16, 1917: circumference 2018 mm. diameters 677 × 555 mm.	24 mm. in 1917–1918 9 mm. in 1918–1919 30 mm. in 1919–1920
Circular *Porites* head in water about 3 feet deep at low tide, about 300 feet offshore on the reef-flat off Fagaalu Village, Apr. 16, 1917: circumference 6,404 mm.	37 mm. in 1917–1918 0 mm. in 1918–1919 54 mm. in 1919–1920
Circular *Porites* head in water about 4 feet deep at low tide off Fagaalu Village, about 32 5feet from shore, Apr. 16, 1917: circumference 1,500 mm.	38 mm. in 1917–1918
Very large, isolated, nearly circular, yellow-colored *Porites* head on the Utelei reef-flat in water about 2 feet deep at low tide. Dimensions on Aug. 25, 1919: circumference (29.1 feet) 8,870 mm., diameter 2,823 mm.	35 mm. in 1919–1920
Cleft near the center of the top of a large *Porites* head off Fagaalu Village. The sides of this cleft are growing toward one another, tending to close the opening. The sides were 296.5 mm. apart on Apr. 14, 1917.	27 mm. 1917–1918 26 mm. 1918–1919 23 mm. 1919–1920

The following gives the annual gain in diameter of three large massive *Porites* heads allied to *P. lutea* (M. Edw. and H.), southwest of the village of Muaivuso, west of Suva Harbor, Viti Levu Island, Fiji, about 120 yards from shore. These heads were dead above at low-tide level, and were growing laterally. The first measurments were made September 2, 1918, and the last April 18, 1920.

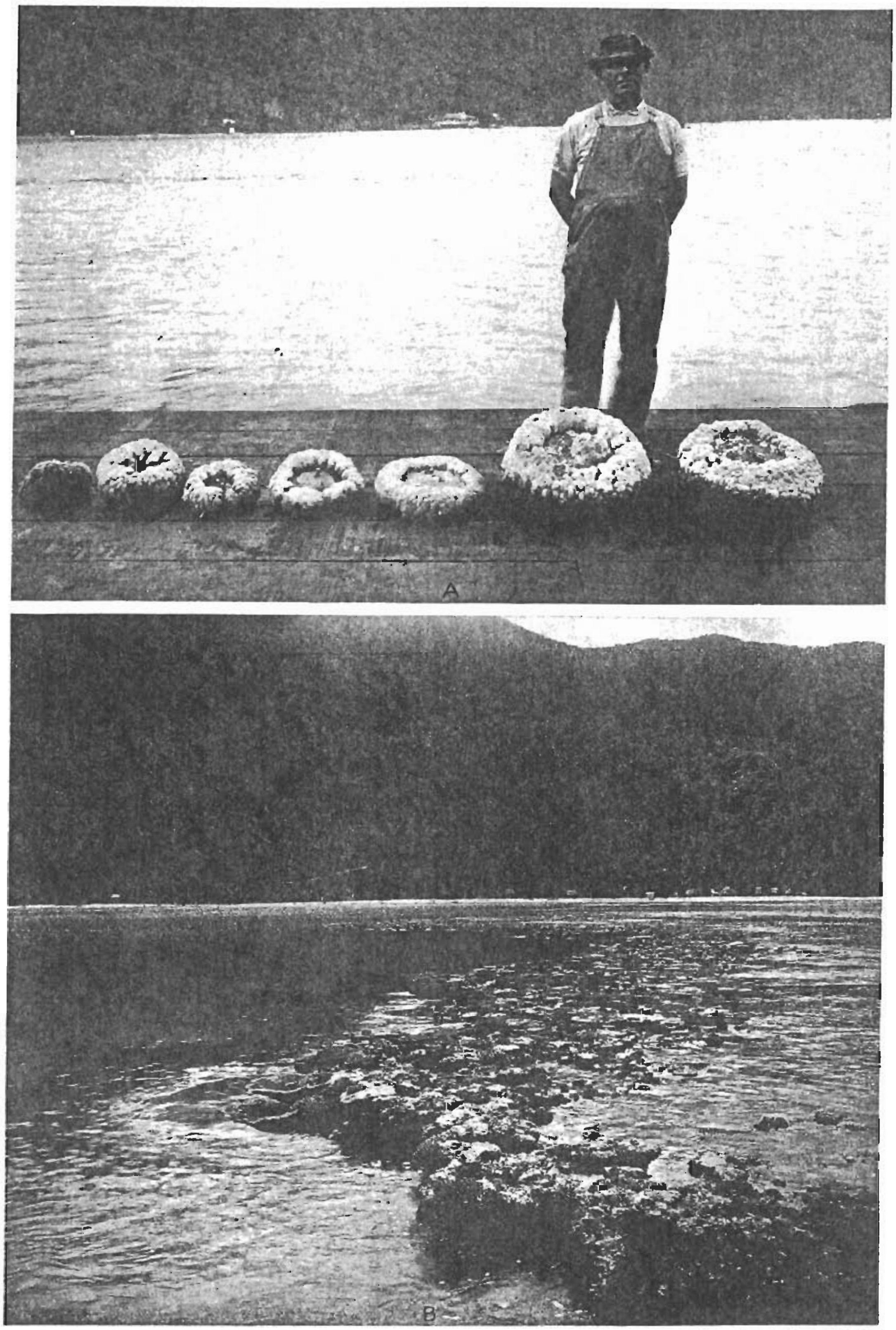
Description of the *Porites* head.	Gain in diameter in 12 months.
Brown-colored, nearly circular *Porites*, growing on a hard bottom covered with some sand and about a foot deep at low tide. Dimensions on Sept. 2, 1918: circumference 8,156 mm. (26.76 feet), diameter 2,596 mm. On April 18, 1920 the dimensions were: circumference 8,321 mm. (27.3 feet), and diameter 2,654 mm.	36 millimeters.
Large brown-colored *Porites* head a few feet south of the one mentioned above. This head was nearly circular in contour, and was dead at low-tide level above, and growing laterally. Dimensions on Sept. 2, 1918: circumference 7,608 mm. (24.76 feet) or 2,421 mm. diameter. On Apr. 18, 1920, the dimensions were: circumference 7,740 mm. (25.39 feet) diameter 2,463 mm.	26 millimeters.
Yellow-colored massive *Porites* head nearly circular in outline. Dead above at low-tide level and growing laterally. About 300 feet S. by W. from the two large brown heads off Mauivuso Village. Dimensions on Sept. 2, 1918: circumference 4,817 mm. (15.77 feet); diameter 1,530 mm.	23 millimeters.
Average gain in diameter per annum of these *Porites* heads from Fagaalu, Utelei, and Muaivuso, 28 mm.	
Average initial circumference 5,091 mm.; average initial diameter 1,620 mm.	

TABLE 8.

Photo. No. and description and name of coral.	Dimensions on July 25, 1919, and June 12, 1920, in millimeters.	Weight on July 25, 1919, and June 12, 1920.	Observed gain in dimension in 10½ months.	Observed gain in weight in 10½ months.
		grams.	*millimeters.*	*grams.*
1 S. *Psammocora contigua* Esper., olive-colored *Psammocora*; the fragile stems of this coral were broken in the half grown in agitated shallow water.	1920; 67 × 32 × 38 high... 1919; 81 × 58 × 55.......	....	—14 × —26 × —17; stems all broken by the agitated water; the surviving stems were all short, thickened, and compact.	
1 D. *Psammocora contigua* Esper., olive-colored *Psammocora*.	1920; 97 × 59 × 53, high... 1919; 71 × 59 × 47.......	....	20 × 0 × 6; the new branches are more slender than the old ones.	
2 S. *Pocillopora damicornis* var. *cespitosa* Dana.	Gone, 1920..............			
2 D. *Pocillopora damicornis* var. *cespitosa* Dana.	1920; 92 × 82 × 66....... 1919; 81 × 79 × 60.......	1920; 85 1919; 71	11 × 3 × 6; new branches more slender than the old ones.	14
3 S. *Acropora* (*Tylopora*) *leptocyathus* (Brook).	1920; 133 × 115 × 81..... 1919; 93 × 64 × 58........	1920; 595 1919; 297	40 × 51 × 23..........	298
3 D. ....Do...........................	Dead, made no growth.....			
4 S. *Acropora fructicosa* (Brook)...........	1920; 161 × 150 × 111.... 1919; 156 × 115 × 75.....	1920; 879 1919; 553	5 × 35 × 36............	326
4 D, ...Do...........................	Dead, made no growth.....			
5 S. *Psammocora contigua* var. *maldivensis* Gardiner, brown-colored *Psammocora*.	1920; 82 × 64 × 41....... 1919; 81 × 63 × 64.......	1920; 92 1919; 113	1 × 1 × —23..........	21 loss
5 D. ....Do...........................	1920; 91 × 71 × 73....... 1919; 79 × 66 × 65.......	1920; 128 1919; 111	12 × 5 × 8...........	17
6 S & 6 D. *Porites lutea M. Edw. and H*	Dead, made no growth.....			
7 S. Drab-colored *Porites andrewsi* Vaughan.	1920; 152 × 101 × 108.... 1919; 152 × 95 × 94......	1920; 312 1919; 213	0 × 6 × 14...........	99
7 D. ....Do...........................	Dead, made a slight growth before dying...........			
8 S. Light-brown *Acropora* (*Tylopora*) *leptocyathus* (Brook).	1920; 122 × 83 × 58...... 1919; 110 × 80 × 58......	1920; 482 1919; 241	12 × 3 × 0...........	241
8 D. ....Do...........................	Died without growing......			
9 S. *Acropora massawensis* von Mar..........	Only a small part living. The remainder dead and corroded in 1920........			
9 D. ....Do...........................	Died, without growing.....			
10 S. *Pocillopora damicornis* var. *cespitosa* Dana.	1920; 99 × 83 × 64....... 1919; 118 × 83 × 46......	1920; 198 1919; 177	—19 × 0 × 18.........	21
10 D. ....Do..........................	1920; 130 × 107 × 67..... 1919; 128 × 104 × 64 half dead..................	1920; 269 1919; 269	2 × 3 × 3............	0
11 S. Olive - green colored *Porites andrewsi* Vaughan.	1920; 139 × 121 × 106..... 1919; 121 × 111 × 81.....	1920; 405 1919; 262	18 × 10 × 25.........	143
11 D. ....Do..........................	1920; 119 × 68 × 104..... 1919; 116 × 69 × 71......	1920; 177 1919; 170	3 × —1 × 33..........	7
12 S & 12 D. *Acropora* sp. aff. *A. samoensis* (Brook).	12 S gone in 1920.......... 12 D died without growing.			
13 S & 13 D. *Acropora* (*Tylopora*) *samoensis* (Brook).	13 S nearly all dead........ 13 D died without growing.			
14 S. *Acropora hebes* (Dana); brown long-stemmed *Acropora*.	1920; 107 × 54 × 87 ...... 1919; 110 × 71 × 105.....	1920; 184 1919; 106	—3 × —17 × —18; stems much thickened.	78
14 D. ....Do..........................	Died without growing.....			

TABLE 8.—Continued.

Photo. No. and description and name of coral.	Dimensions on July 25, 1919, and June 12, 1920, in millimeters.	Weight on July 25, 1919, and June 12, 1920.	Observed gain in dimension in 10½ months.	Observed gain in weight in 10½ months.
		grams.	*millimeters.*	*grams.*
15 S. *Pavona divaricata* Lamarck; light-brown *Pavona*.	1920; 92 × 43 × 48 1919; 75 × 36 × 32	1920; 149 1919; 99	17 × 7 × 16; fronds very compact and thick set.	50
15 D. ....Do	1920; 101 × 63 × 58 1919; 104 × 62 × 36	1920; 170 1919; 156	7 × 1 × 22	14
16 S & 16 D. Dark-brown *Porites andrewsi* Vaughan.	Both half dead			
17 S. *Psammocora contigua* var. *maldivensis* Gardner; light green *Psammocora*	1920; 96 × 60 × 45 1919; 97 × 53 × 47	1920; 136 1919; 106	—1 × 7 × —2; short stumpy stems.	30
17 D. ....Do	1920; 89 × 58 × 56 1919; 86 × 54 × 47	....	3 × 4 × 9; new branches slender.	
18 S. Massive *Porites*, *P. lutea* var. *haddoni* Vaughan.	1920; 94 × 74 × 78 1919; 78 × 68 × 62	1920; 404 1919; 255	16 × 6 × 16	149
18 D. ....Do	About half dead in 1920			
19 S & 19 D. Massive *Porites*, *P. lutea* var. *haddoni* Vaughan.	Both about half dead in 1920; made slight growth.			
20 S & 20 D. *Pocillopora brevicornis* (Lamarck) brown-colored *Pocillopora*.	20 S only about ¼ of the coral alive in 1920; 20 D died without growing.			
21 S. Dark-brown *Pocillopora damicornis* var. *cespitosa* Dana.	1920; 67 × 54 × 44 1919; 108 × 40 × 58	1920; 57 1919; 100	—41 × 14 × —18; stems short and compact.	—43
21 D. ....Do	1920; 122 × 79 × 74 1919; 102 × 64 × 56	1920; 127 1919; 113	20 × 15 × 18; new stems very slender.	14
22 S & 22 D. Olive-colored massive *Porites* aff. *P. lutea* var. *haddoni* Vaughan.	22 S gone in 1920; 22 D alive, but made very little growth, increase in diameter only 2 mm.			
23 S. Dark-brown *Porites andrewsi* Vaughan	1920; 112 × 85 × 69 1919; 107 × 81 × 60	1920; 227 1919; 186	5 × 4 × 9	41
23 D. ....Do	Died without growing			
24 S. Light-green *Porites andrewsi* Vaughan	Gone 1920			
24 D. ....Do	1920; 156 × 124 × 129 1919; 128 × 116 × 82	1920; 326 1919; 256	28 × 8 × 47; new branches very slender in comparison with the old ones	70



A.—Seven small heads of *Porites* aff. *P. Lutea* grown off Fagaalu, Pago Pago Harbor, from August 1, 1918, to August 23, 1919. (See table 5).

B.—Edge of reef patch off Aua Village, Pago Pago Harbor, in a calm at low tide, showing overhanging edge of reef and clusters of *Acropora leptocyathus* growing on the lithothamnium ridge of the reef-edge. The large bracket-like vase-shaped coral in the middle distance is *Acropora hyacinthus*, a coral characteristic of pure agitated water.

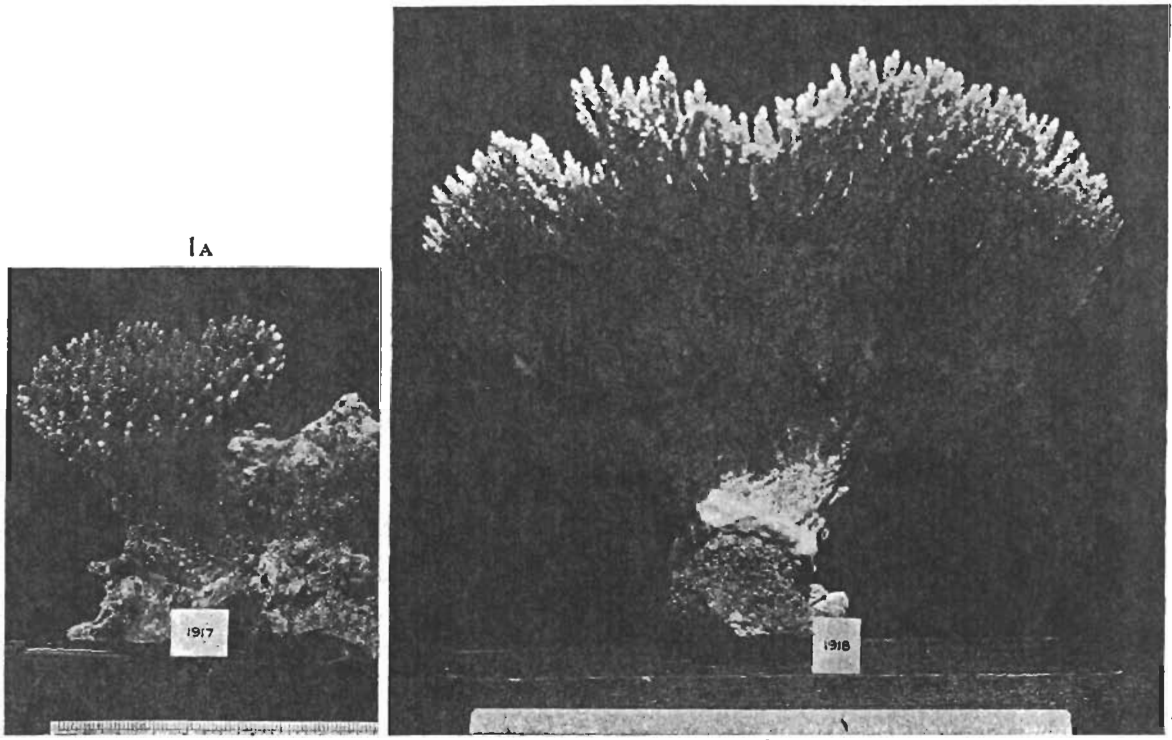
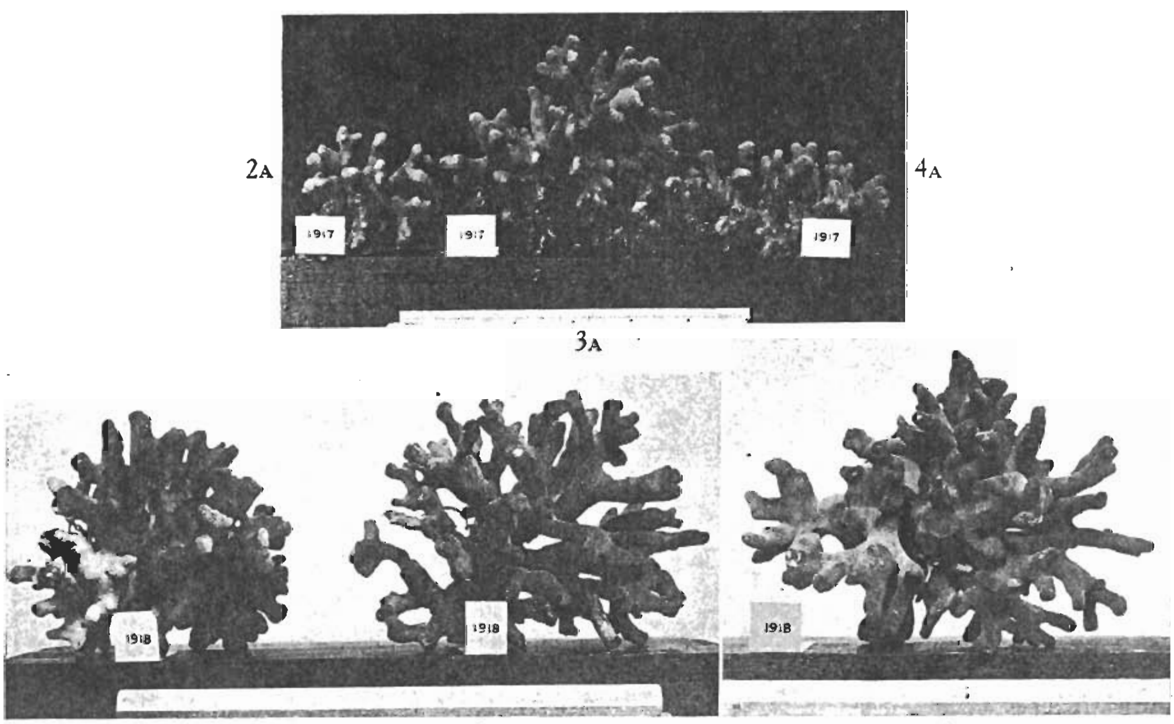


Fig. 1.—Acropora hyacinthus (Dana).



2B 3B 4B

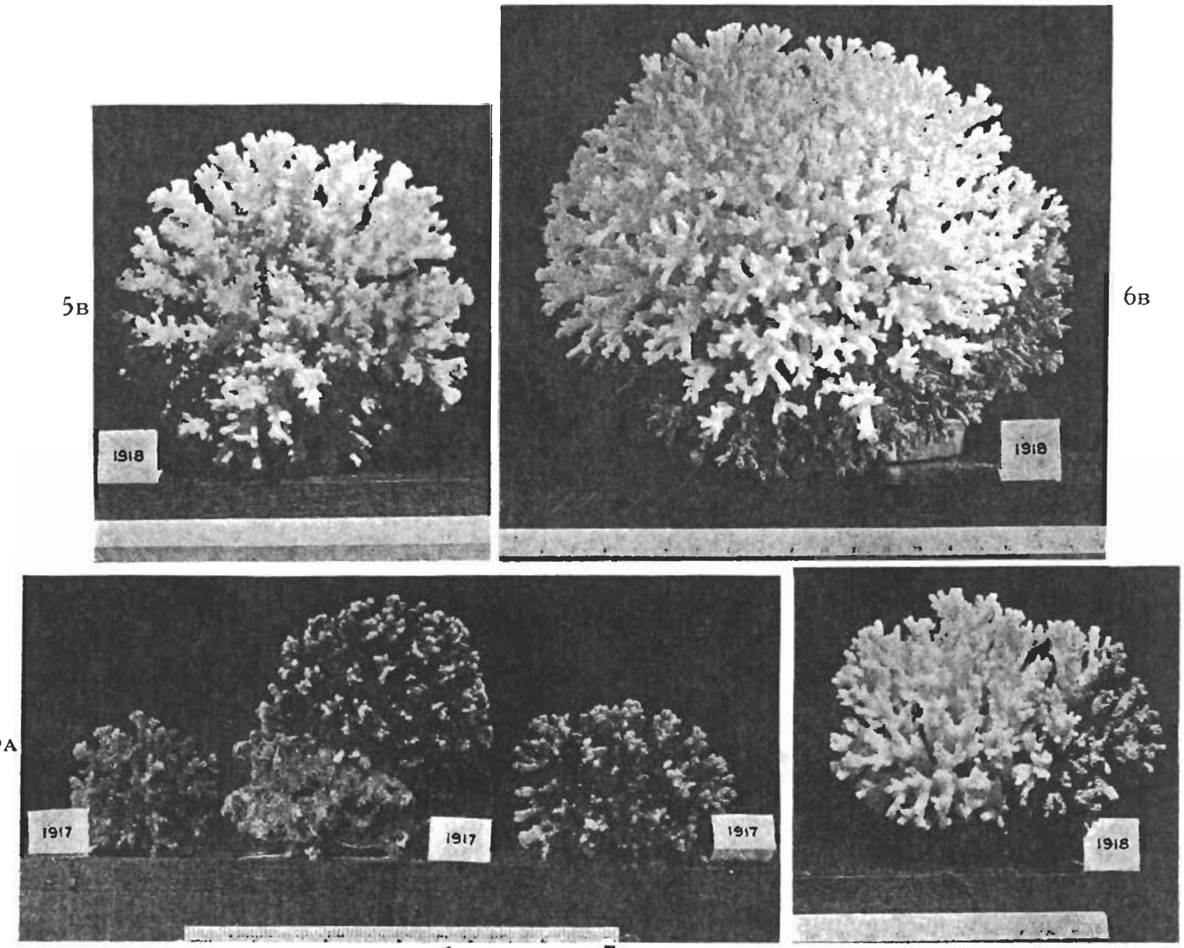
Figs. 2 to 4.—Porites andrewsi Vaughan.

NOTE.—In these plates, A represents the coral when it was taken out of the water for a short time, photographed, embedded in concrete, and returned to the water; the B of the same number shows the same coral at a later date when it was collected for the last time. In all cases, D represents a colony, or half of a colony, which was grown in deep water; S represents a colony, or half of a colony, which was grown in shallow water. This is thoroughly explained on pages 54, 55, and 69. J. E. H.

5B 6B

5A 7B

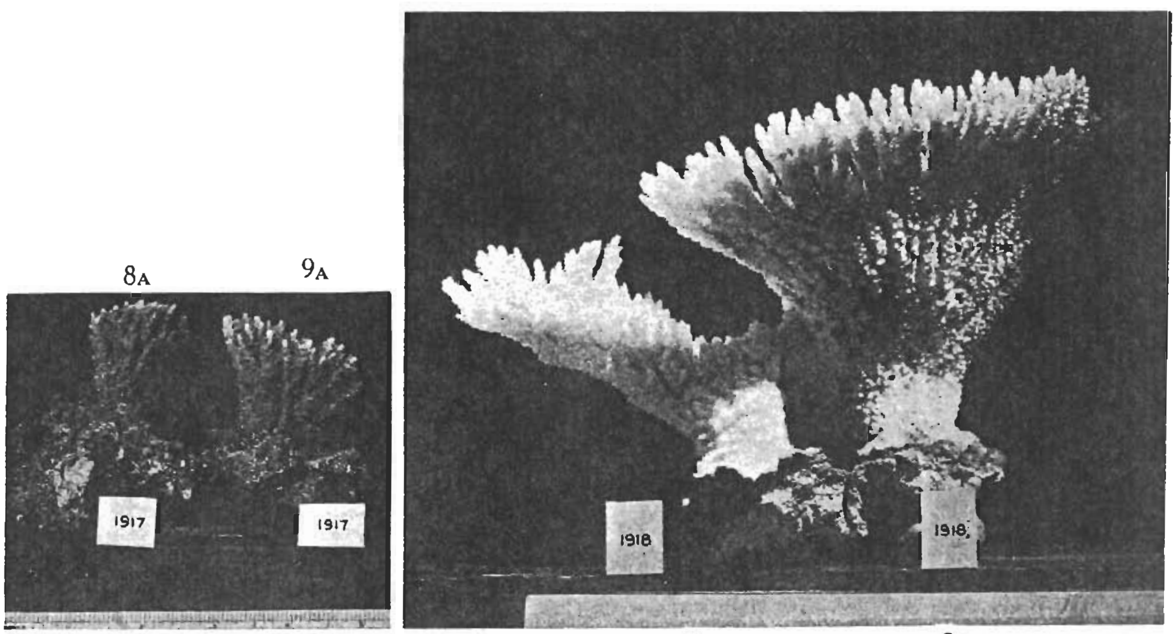
6A 7A



Figs. 5 to 7.—Pocillopora damicornis var. cespitosa Dana.

8A 9A

8B 9B



Figs. 8, 9.—Acropora hyacinthus (Dana).

11A 11B

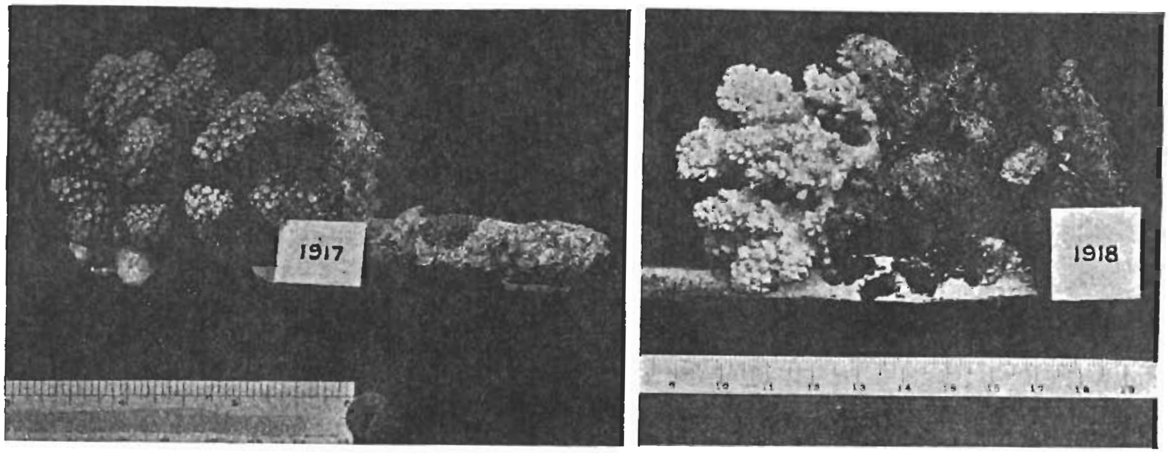


Fig. 11.—Acropora aff. A. humilis (Dana).

12A 12B

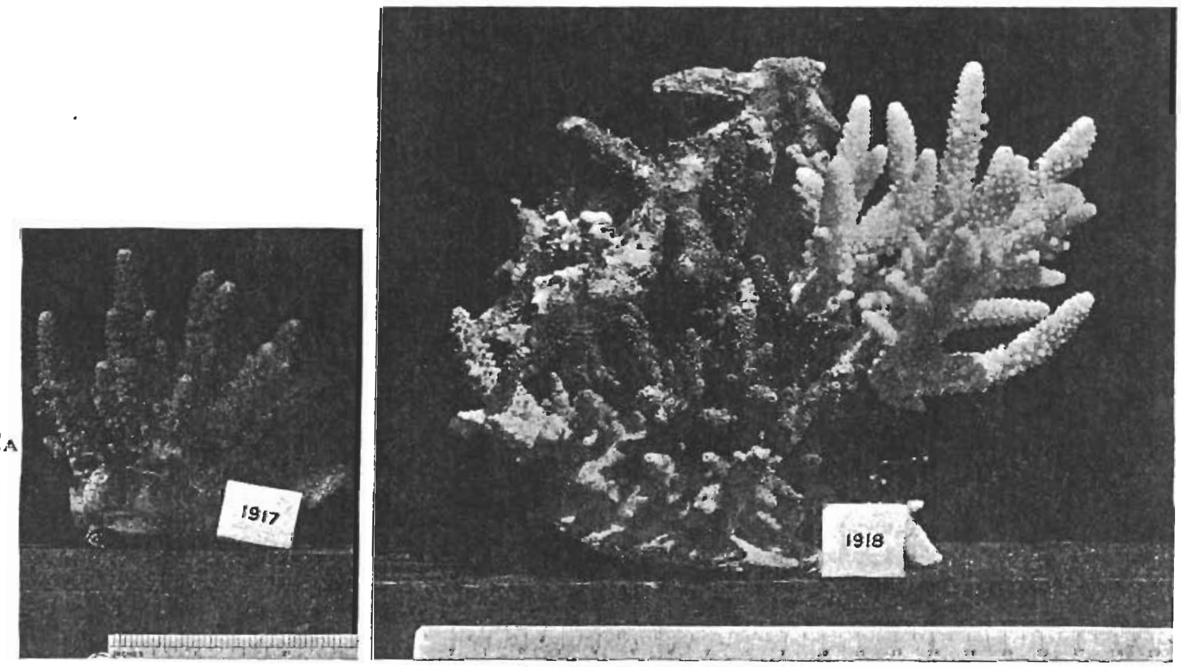


Fig. 12.—Acropora (Tylopora) samoensis (Brook).

15A 15B

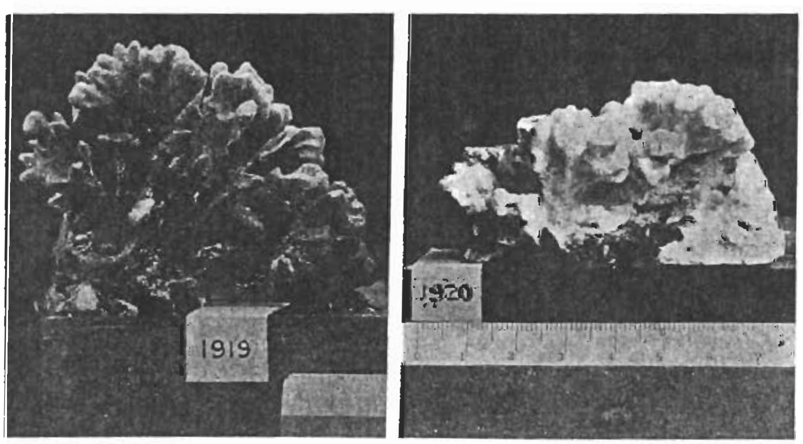
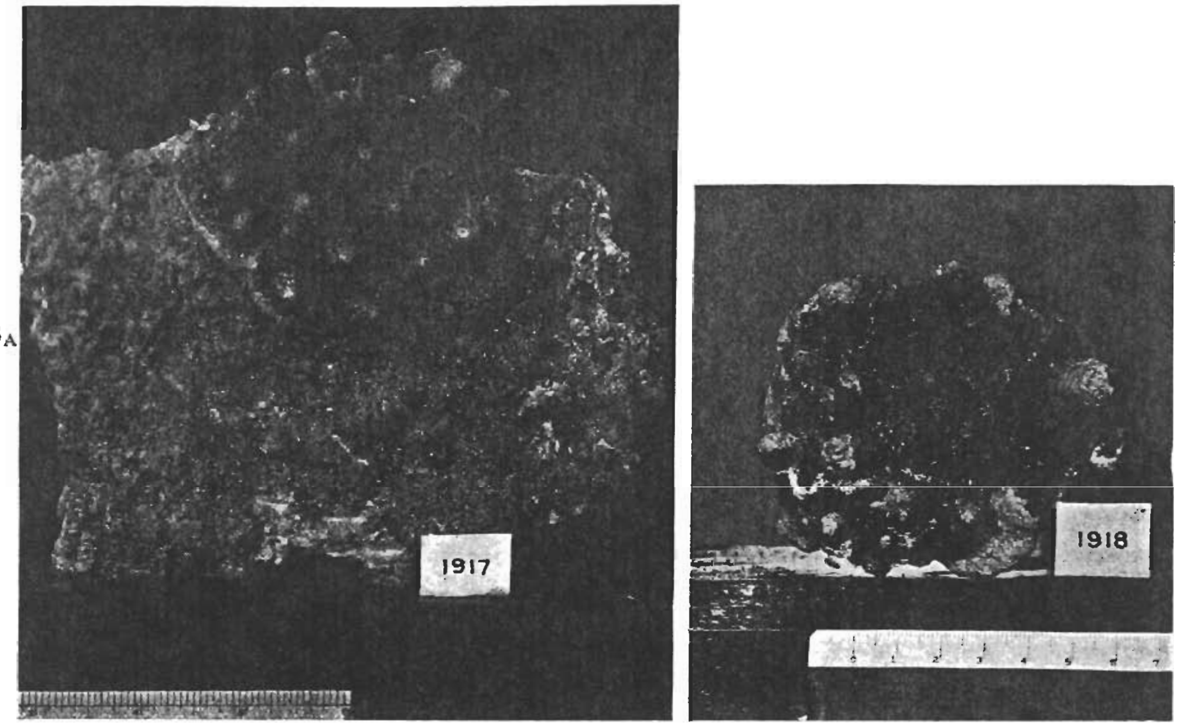


Fig. 15.—Pavona divaricata Lamarck.

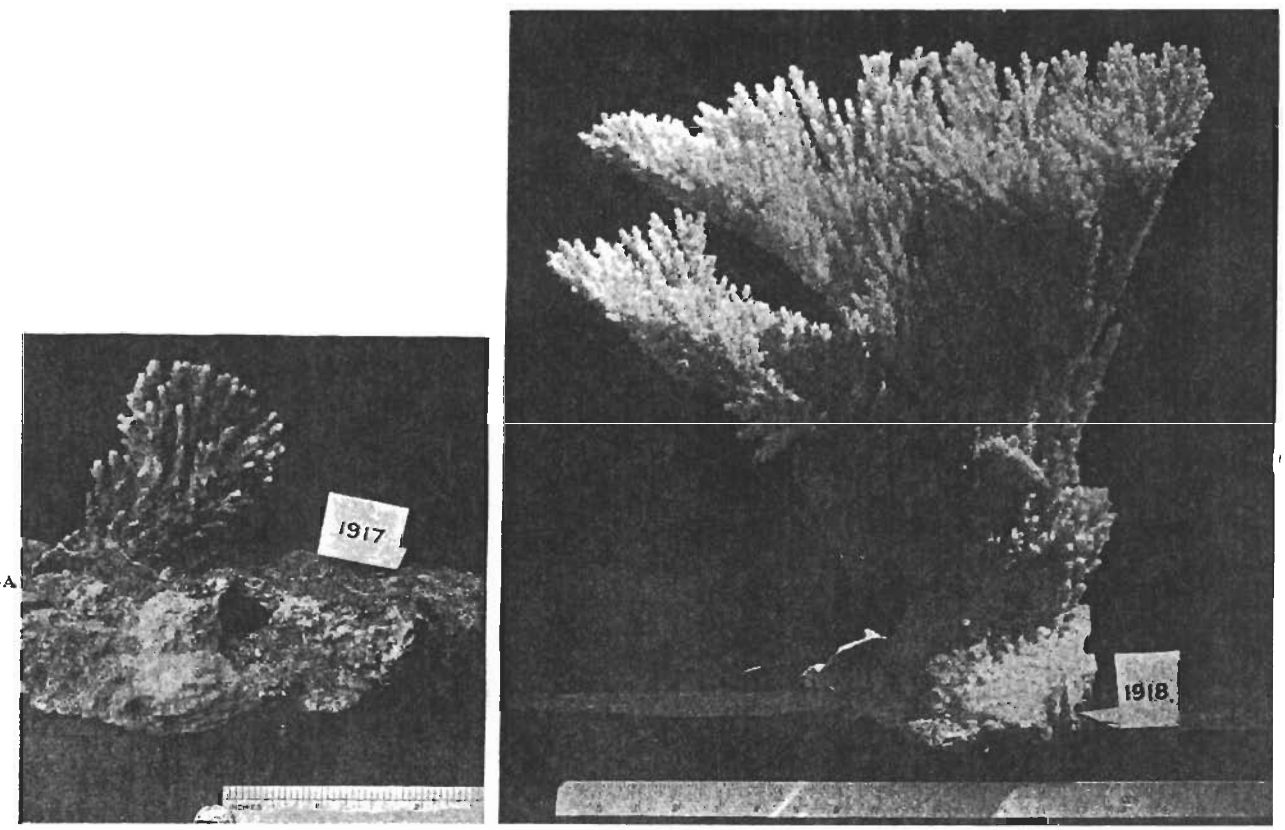
13A



13B

Fig. 13.—Acropora (Tylopora) leptocyathus (Brook).

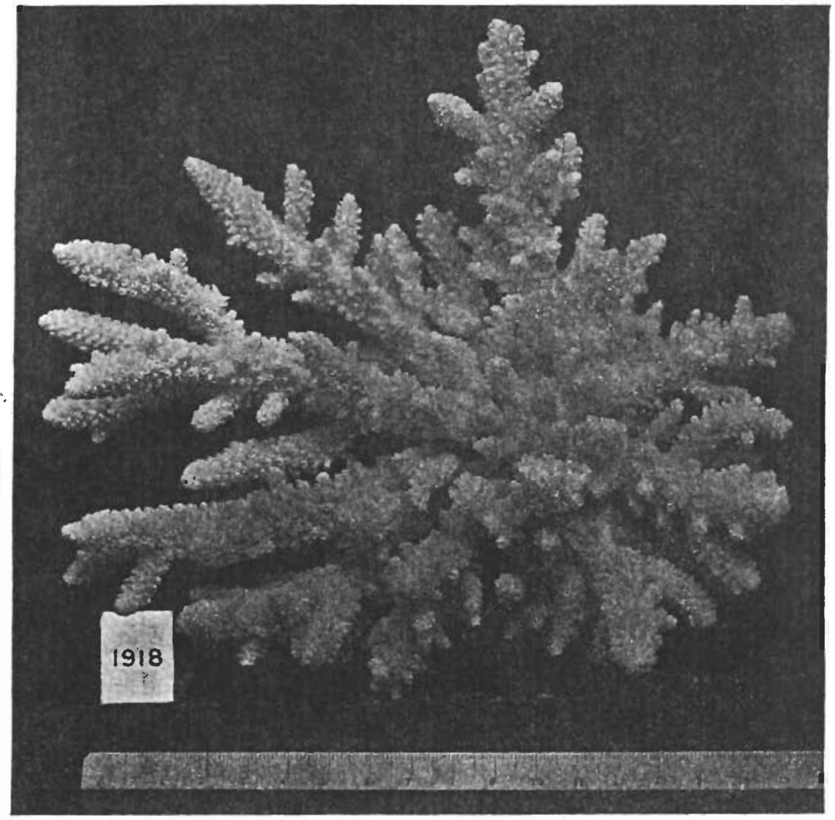
14A



14B

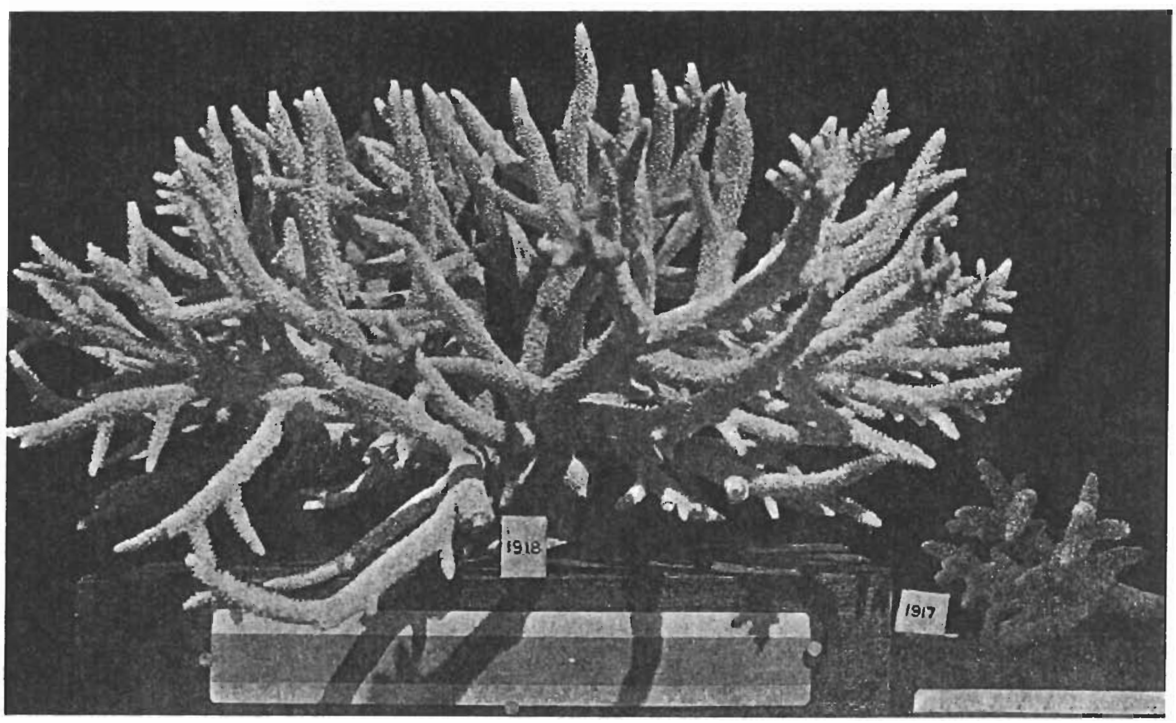
Fig. 14.—Acropora hyacinthus (Dana).

16A



16B

Fig. 16.—Acropora (Tylopora) samoensis (Brook).



19B Fig. 19.—Acropora teres (Verrill). 19A

20A 20B

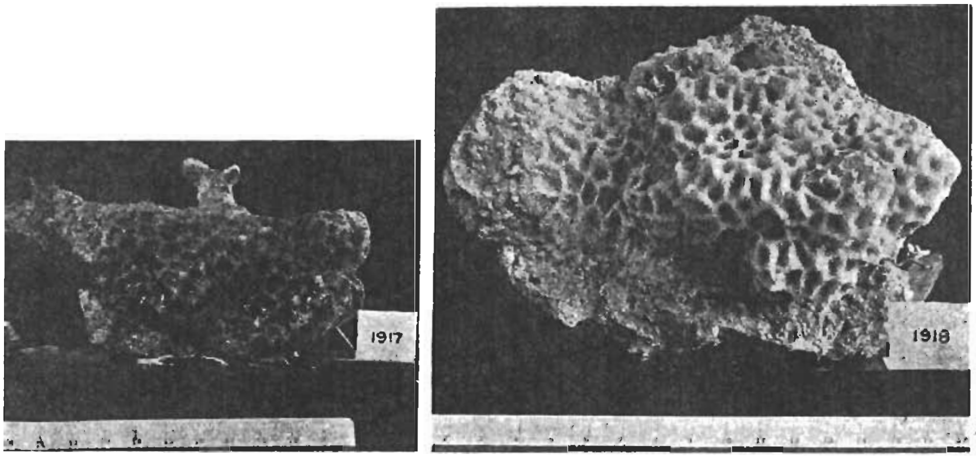


Fig. 20.—Favites abdita (Ellis and Solander).

17A 17B

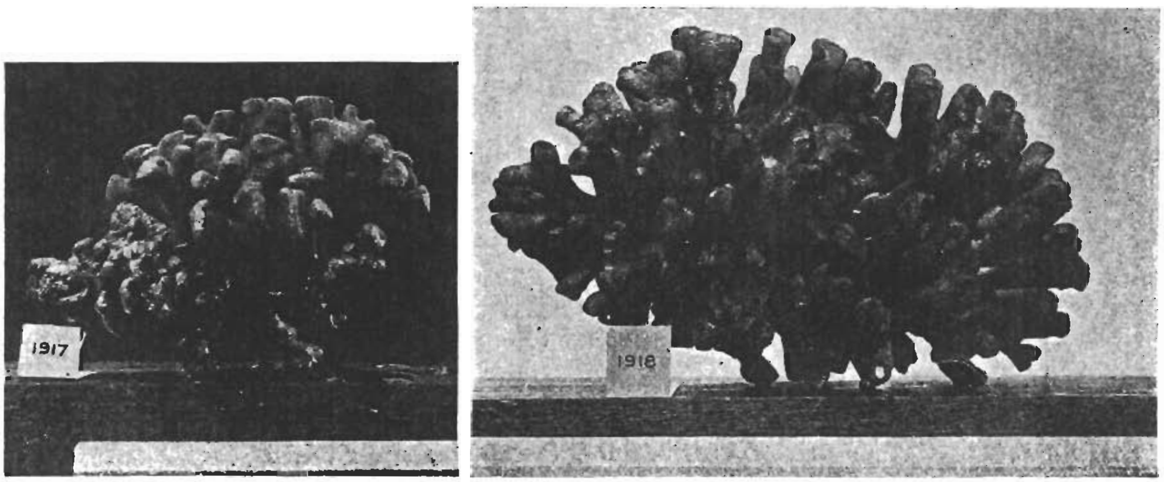


Fig. 17.—Porites andrewsi Vaughan.

18A 18B

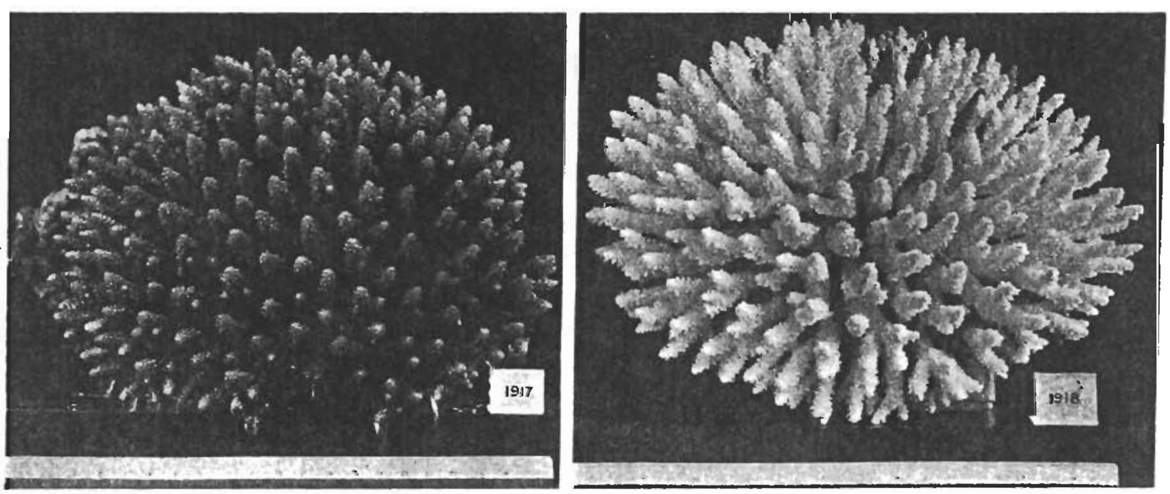


Fig. 18.—Acropora (Polystachis) cymbicyathus (Brook).

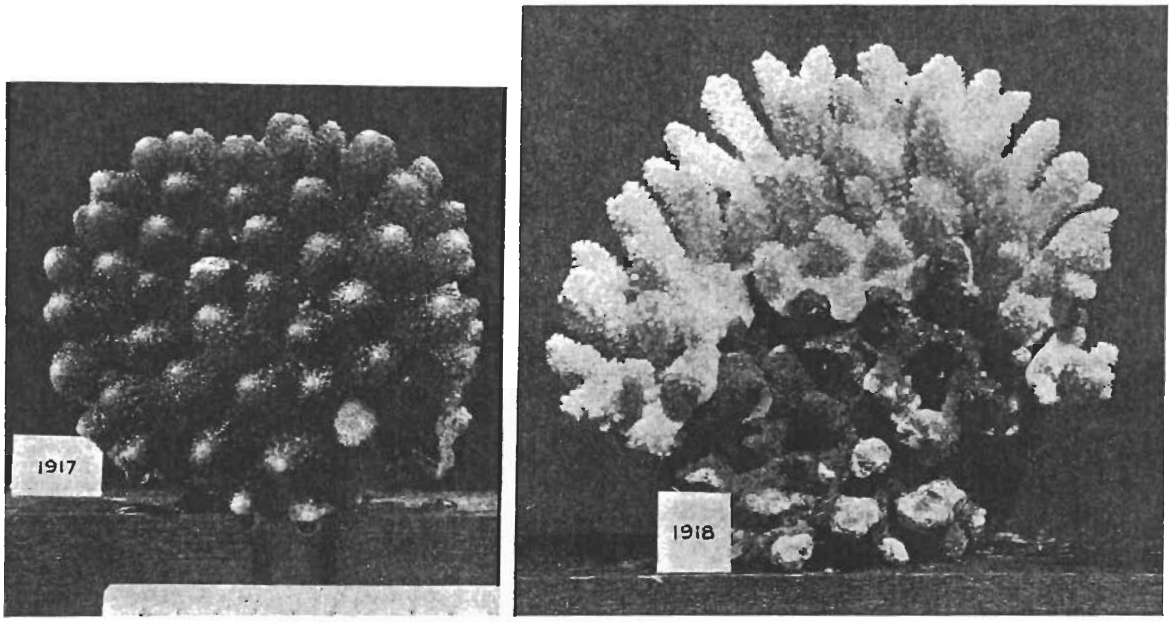
22A  22B

Fig. 22.—Acropora (Tylopora) leptocyathus (Brook).

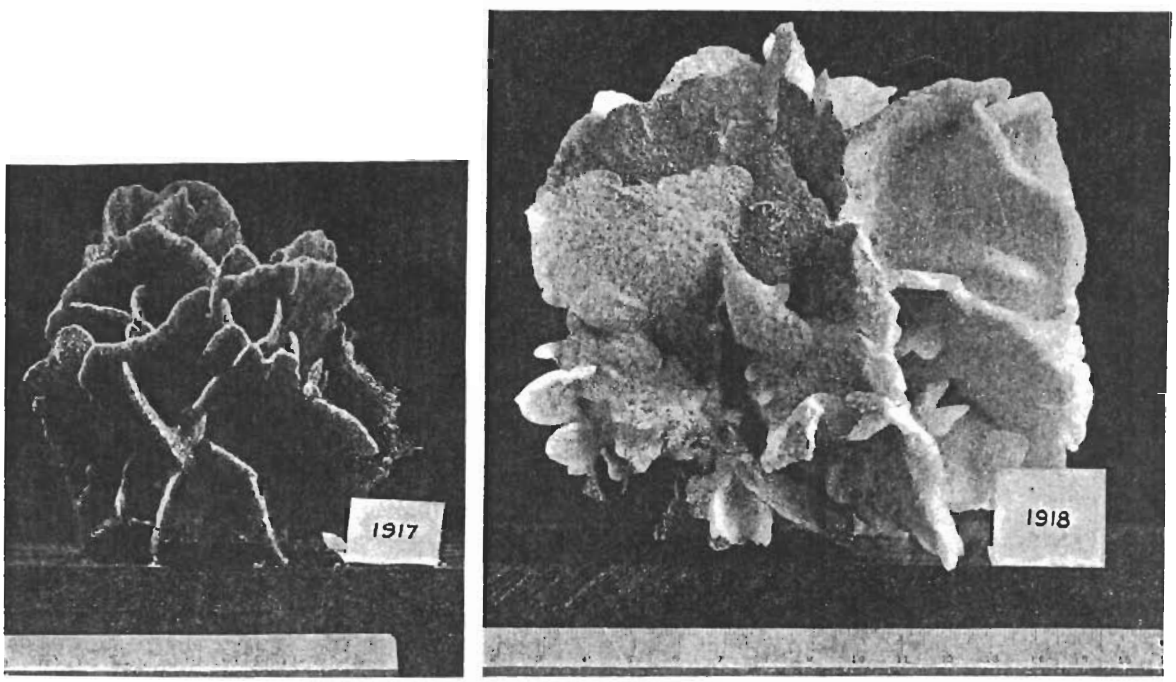
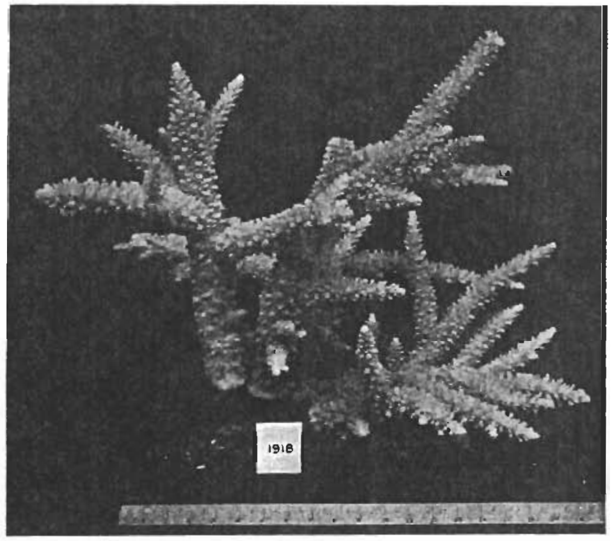
23A  23B

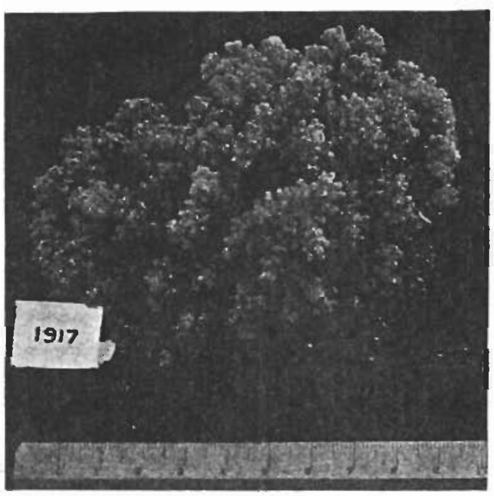
Fig. 23.—Pavona decussata Dana.

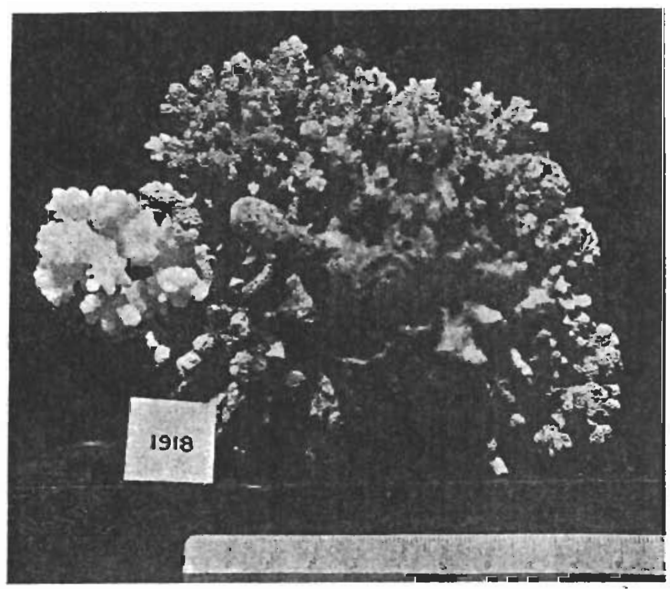
24A

24B

Fig. 24.—Acropora vanderhorsti Hoffmeister.

28A




28B

Fig. 28.—Pocillopora damicornis var. cespitosa Dana (*brevicornis* facies).

29A 29B

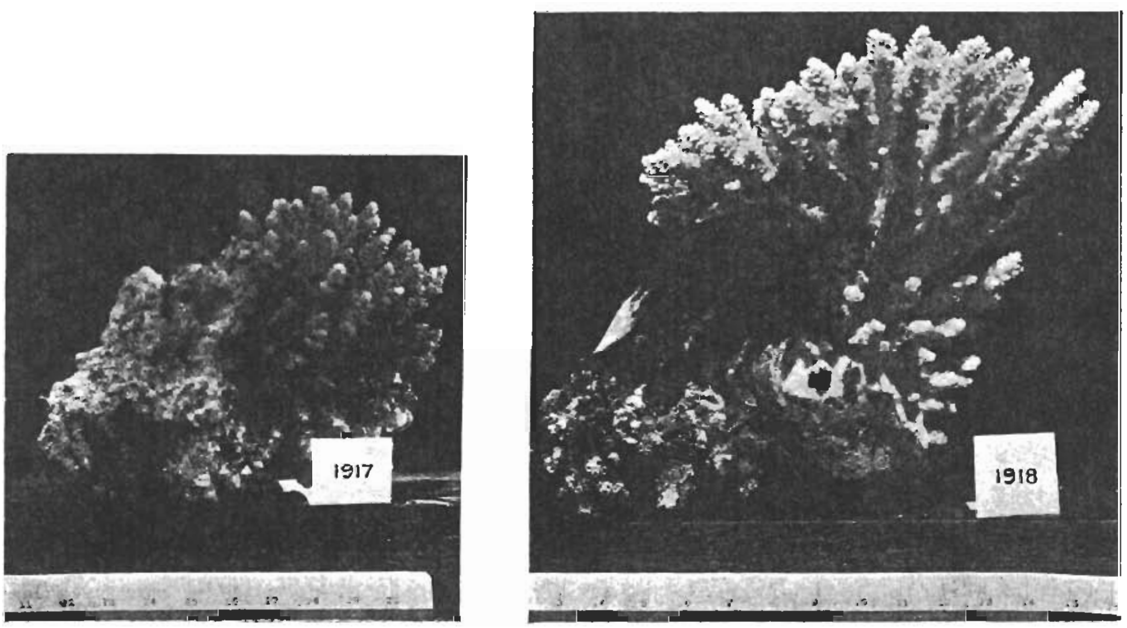


Fig. 29.—Acropora corymbosa (Lamarck).

30A 30B

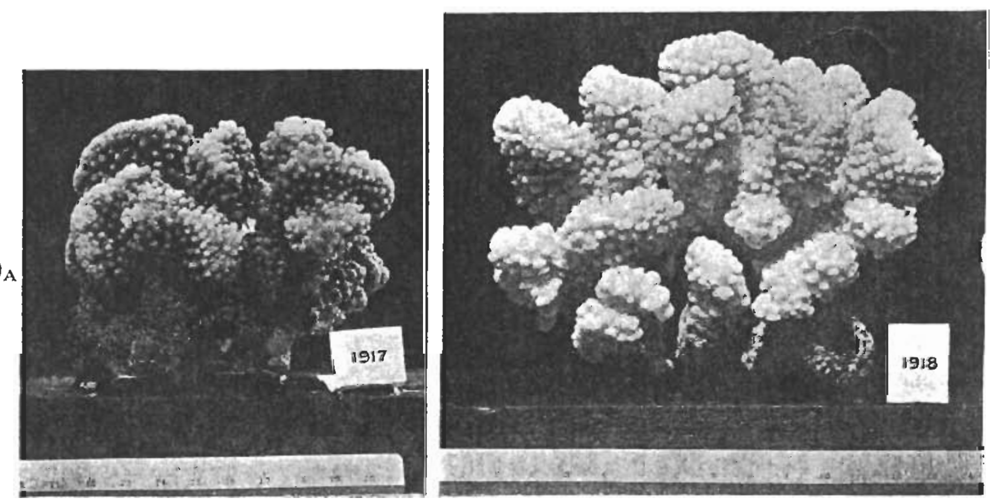
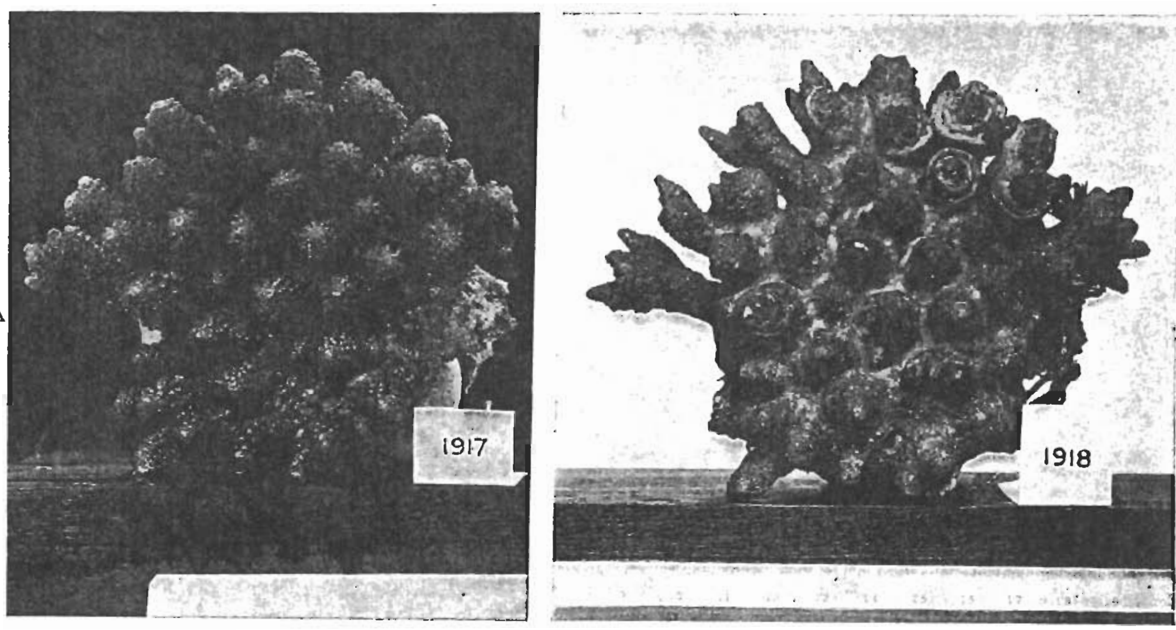


Fig. 30.—Pocillopora eydouxi M. Ed. and H.

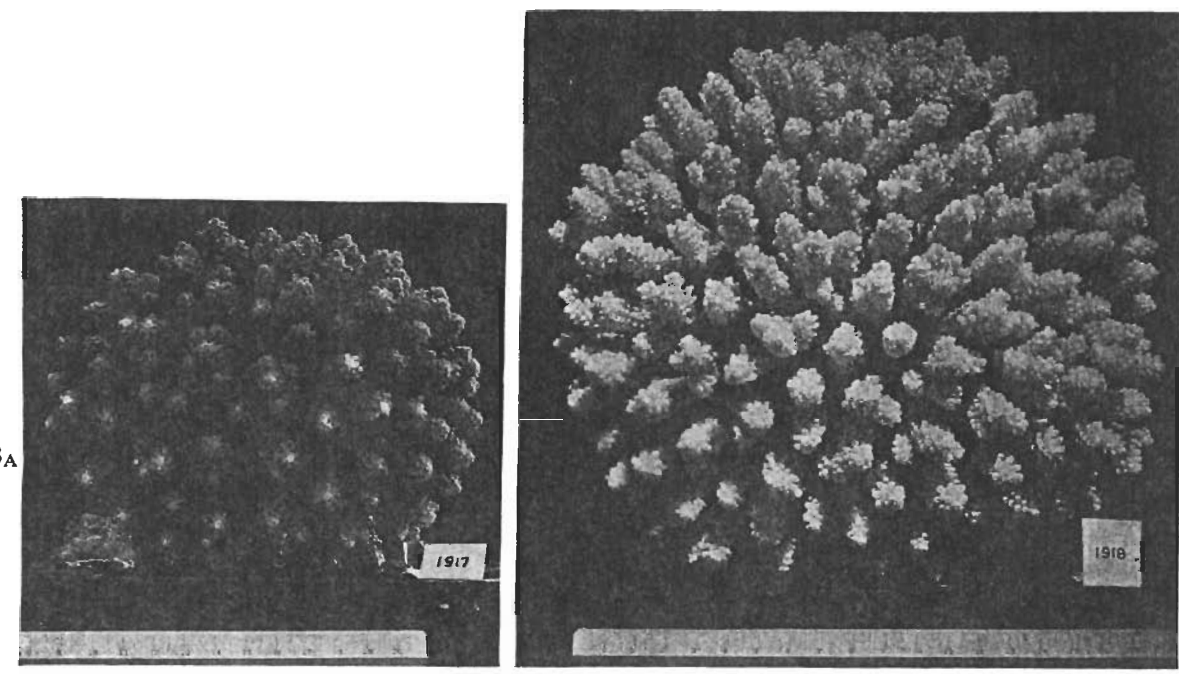
32A



32B

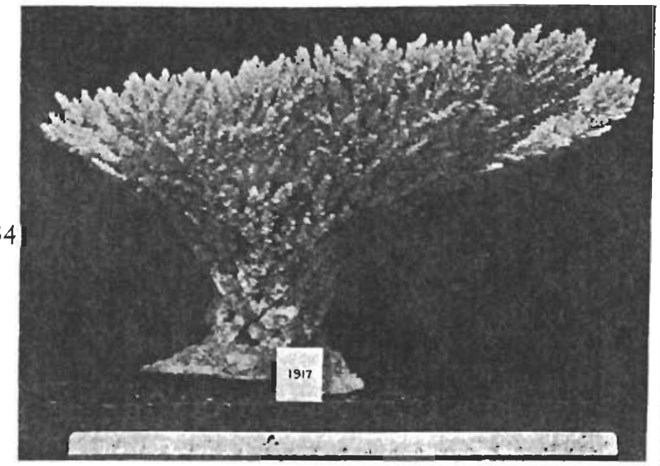
Fig. 32.—Acropora (Tylopora) leptocyathus (Brook).

33A



33B

Fig. 33.—Acropora (Conocyathus) valida (Dana).

34


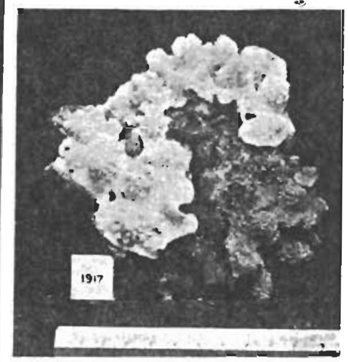
35


Fig. 34.—Acropora hyacinthus (Dana).
Fig. 35.—Acropora (Tylopora) leptocyathus (Brook).

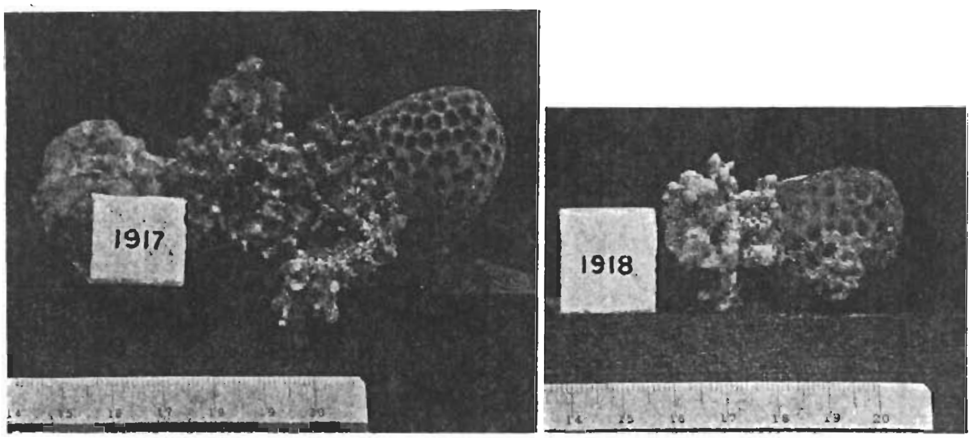
36A 36B


Fig. 36.—Leptastrea purpurea (Dana).

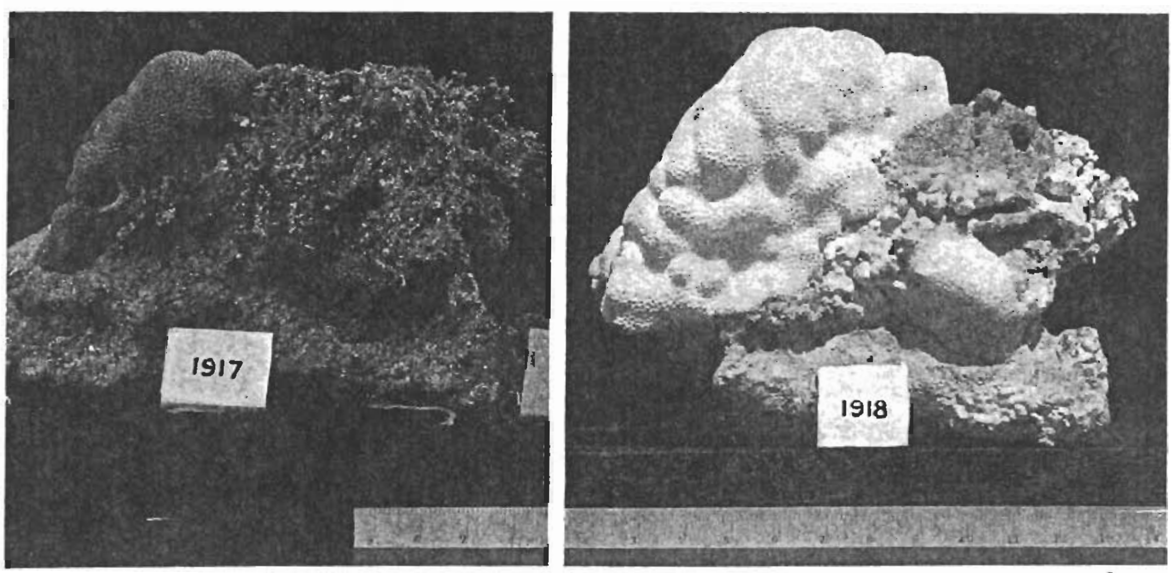
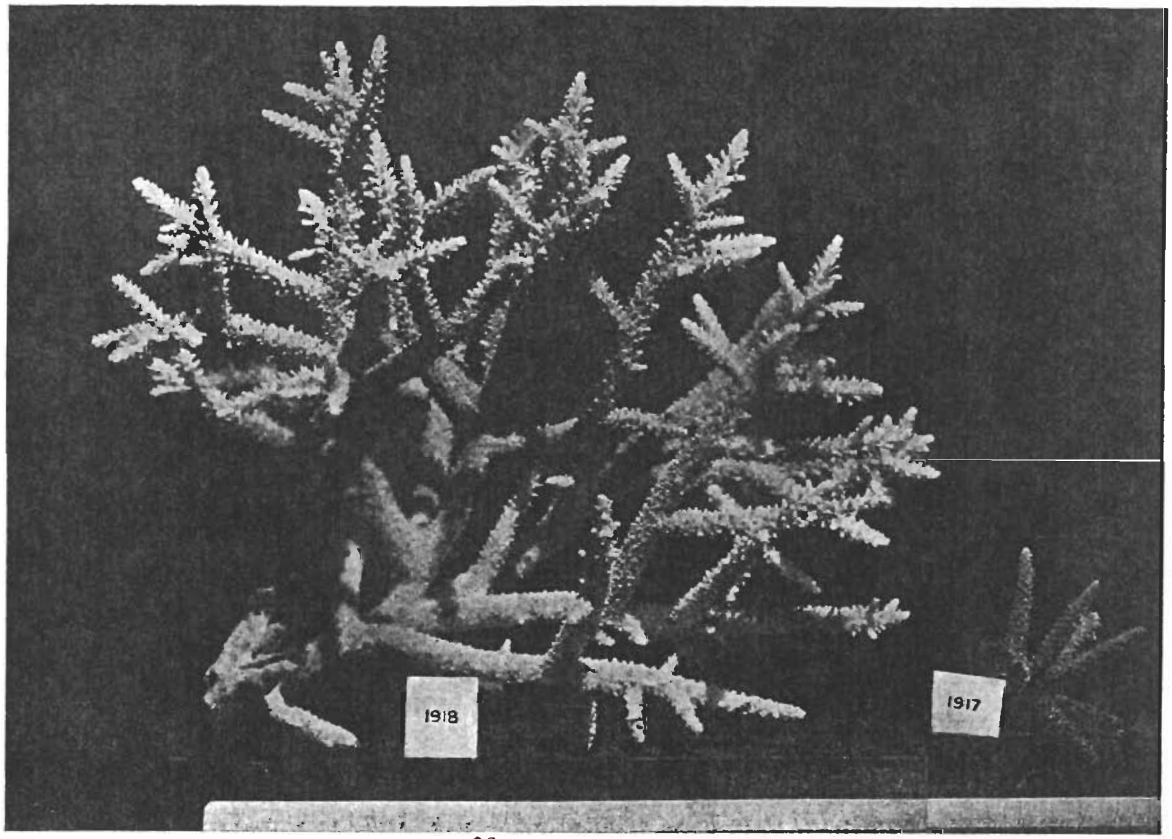
37A 37B


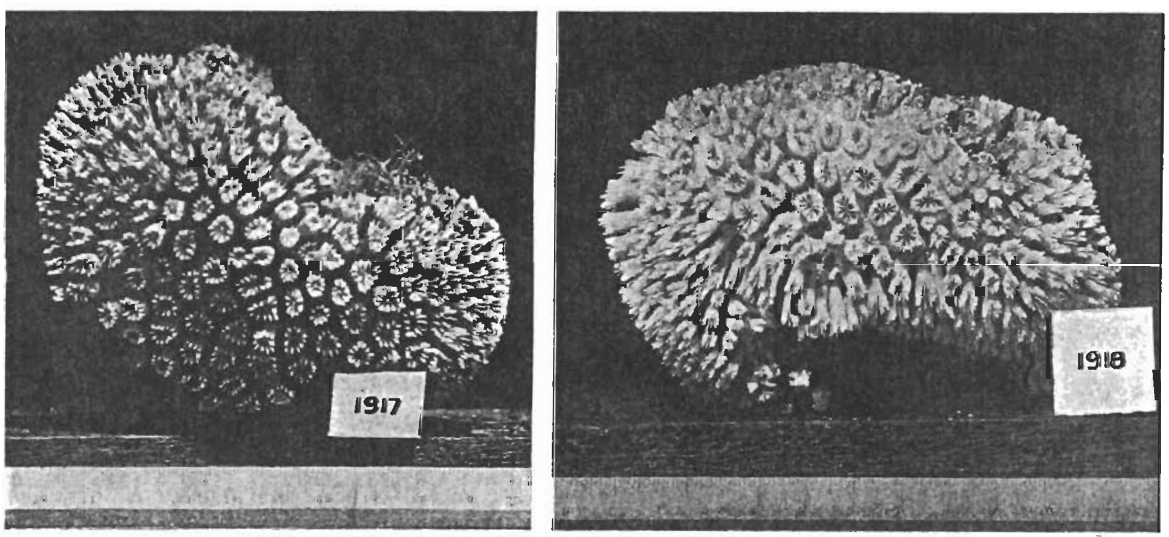
Fig. 37.—Porites aff. P. lutea M. Edw. and H.



38B 38A

Fig. 38.—Acropora aff. formosa var. gracilis (Dana).

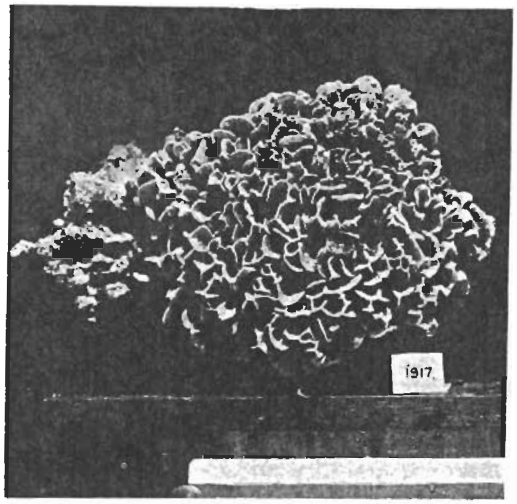
48A



48B

Fig. 48.—Galaxea fascicularis (Linn.).

49A



49B

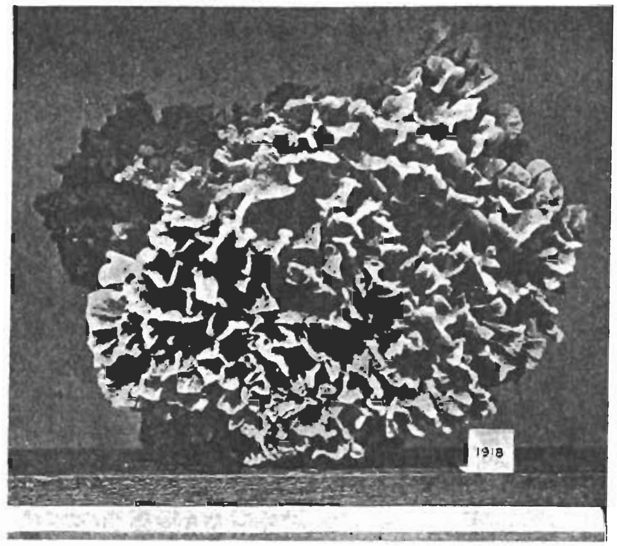
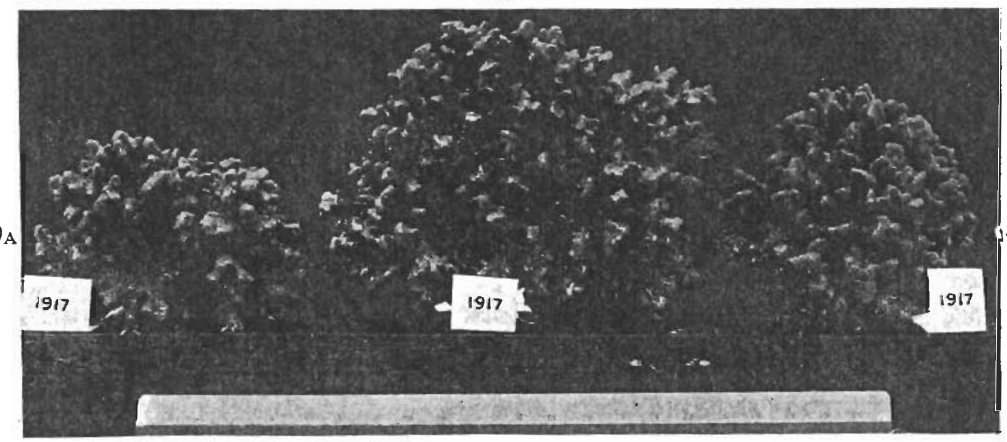


Fig. 49.—Pavona frondifera Lamarck.

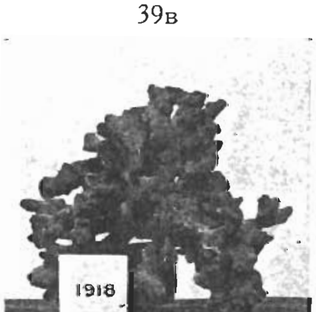
40A

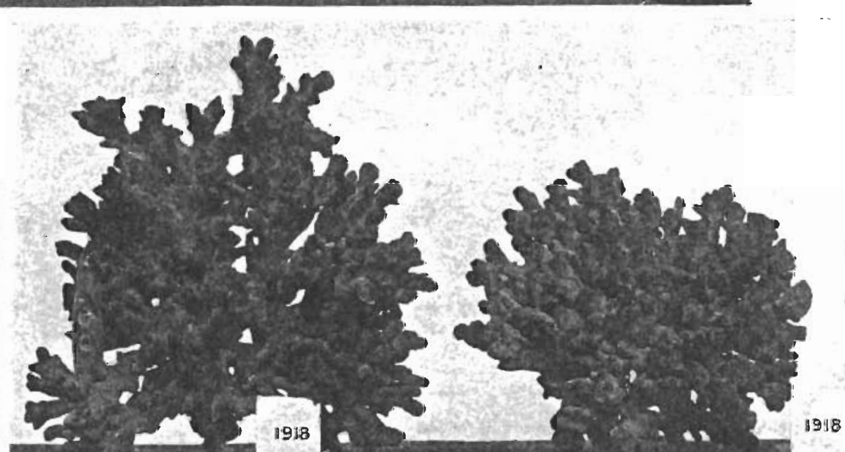
39A



41A

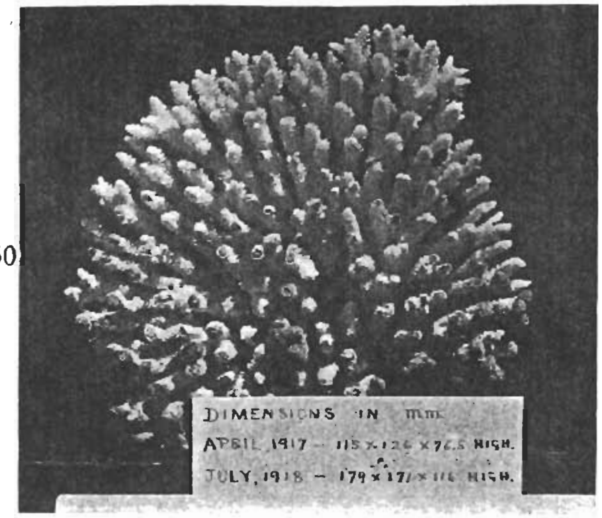
39B





40B 41B

Figs. 39 to 41.—Psammocora contigua var. maldivensis Gardiner.

50


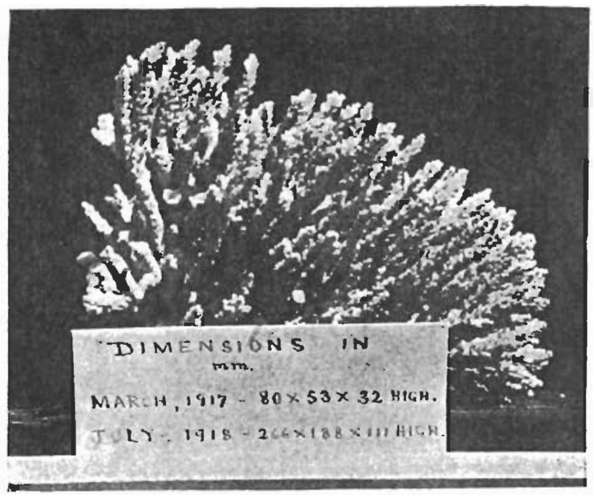
51


Fig. 50.—Acropora corymbosa (Lamarck).
Fig. 51.—Acropora syringodes (Brook).

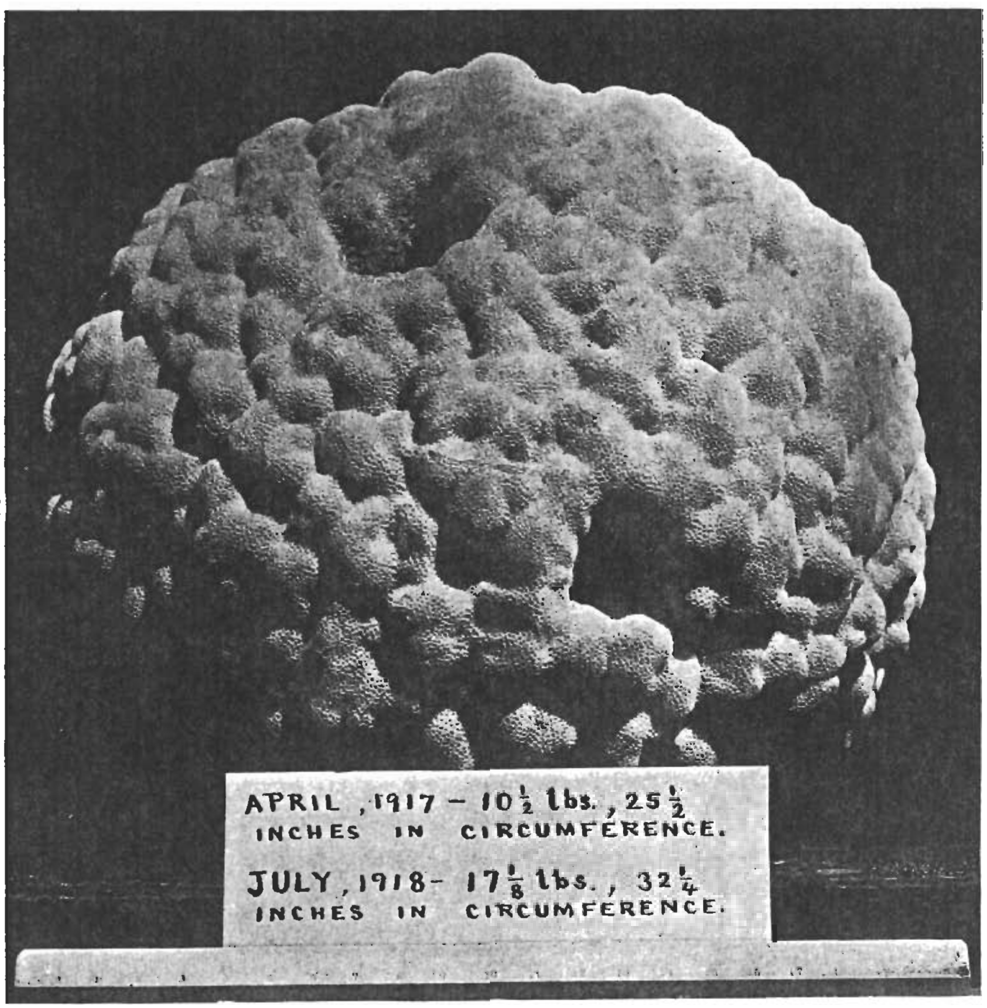
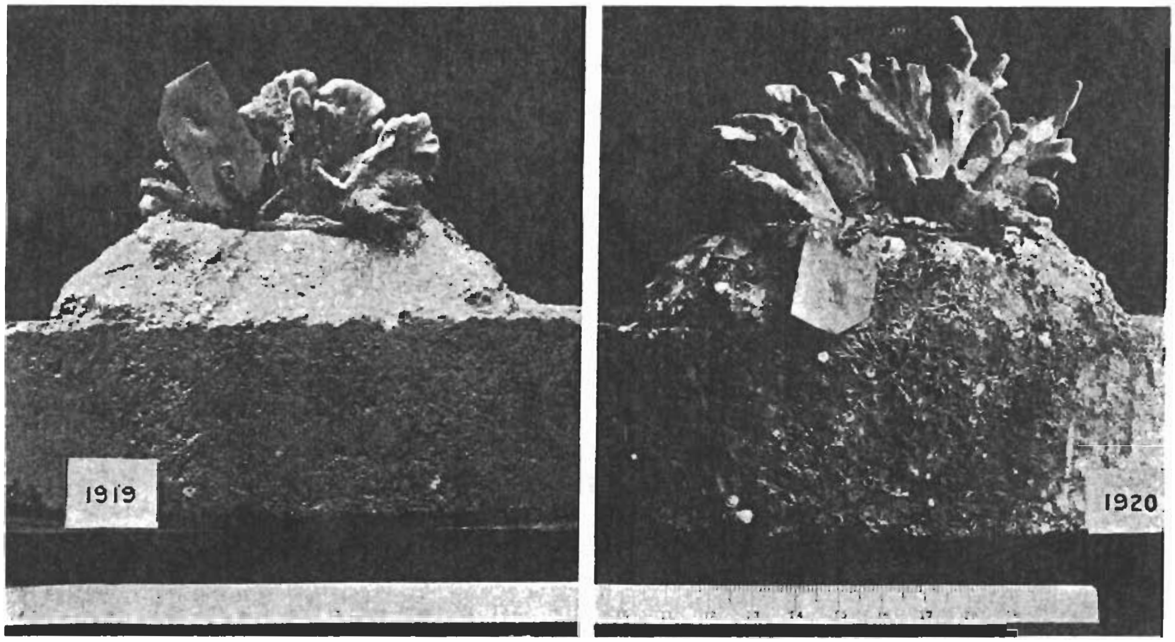
52


Fig. 52.—Porites lutea var. haddoni Vaughan.

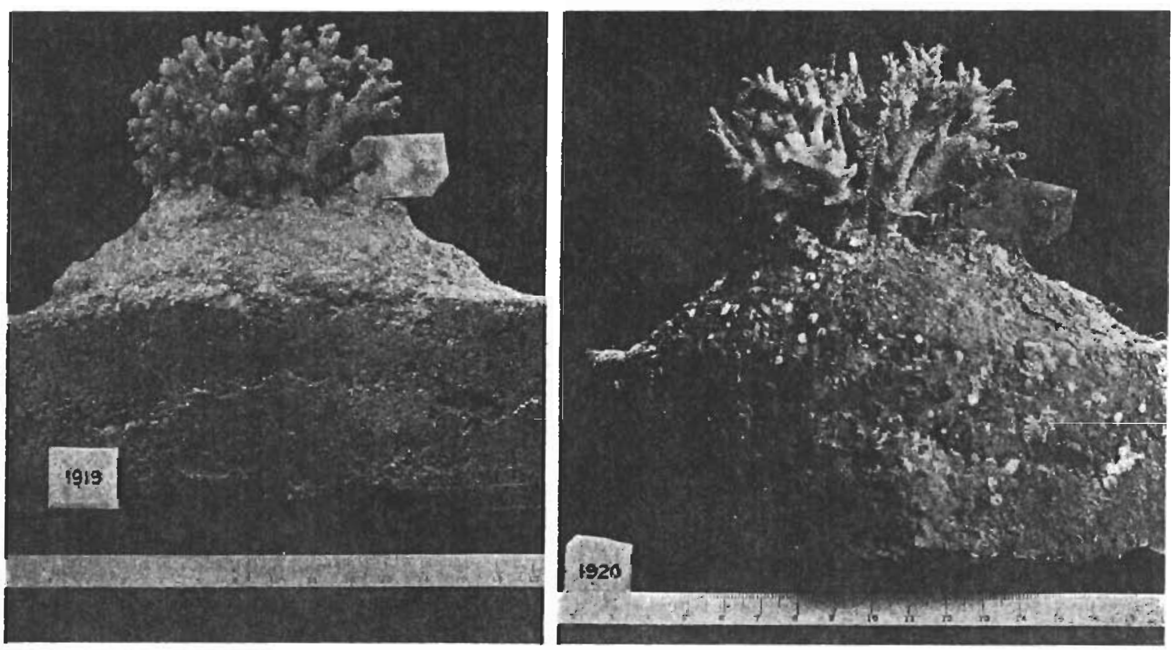
1DA



1DB

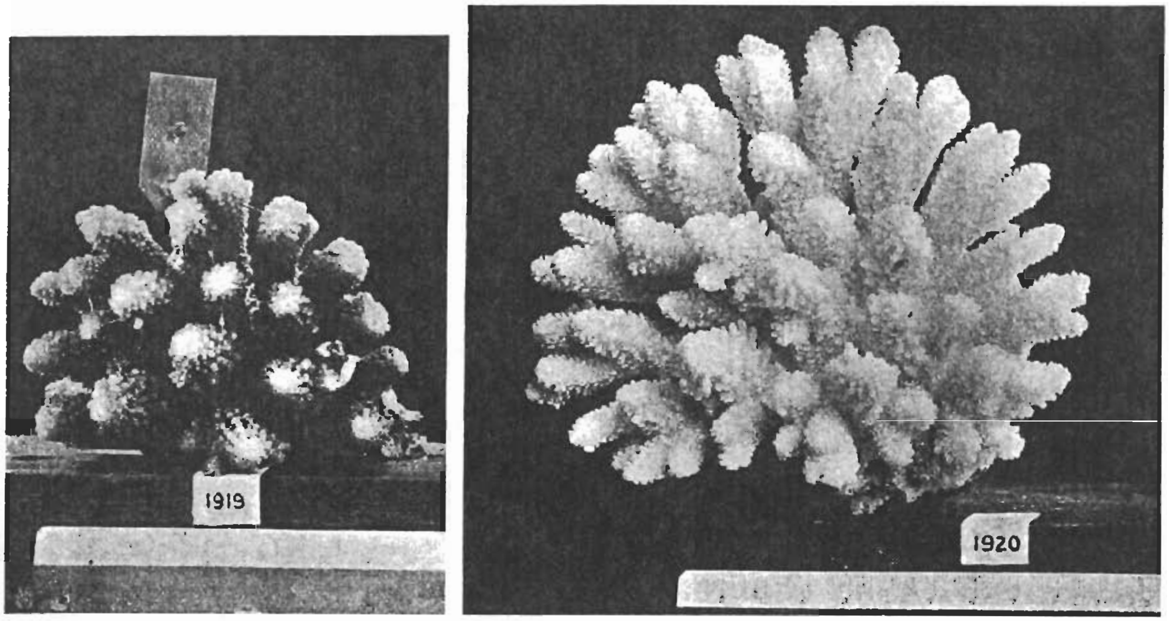
Fig. 1D.—Psammocora contigua Esper.

2DA

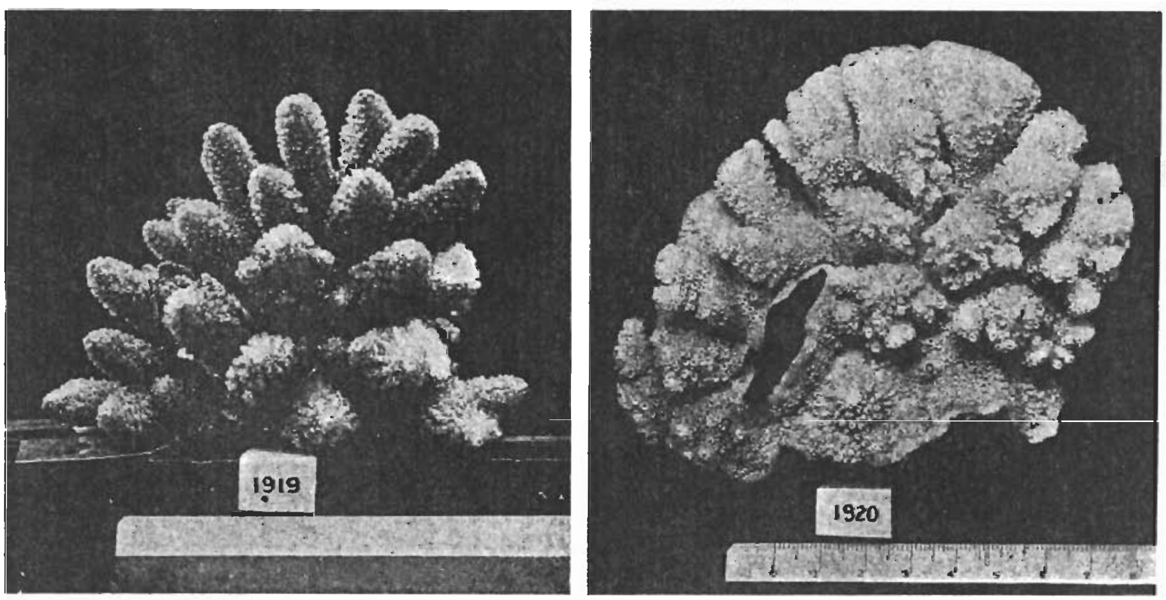


2DB

Fig. 2D.—Pocillopora damicornis var. cespitosa Dana.



3SA Fig. 3S.—Acropora (Tylopora) leptocyathus (Brook). 3SB

8SA


8SB

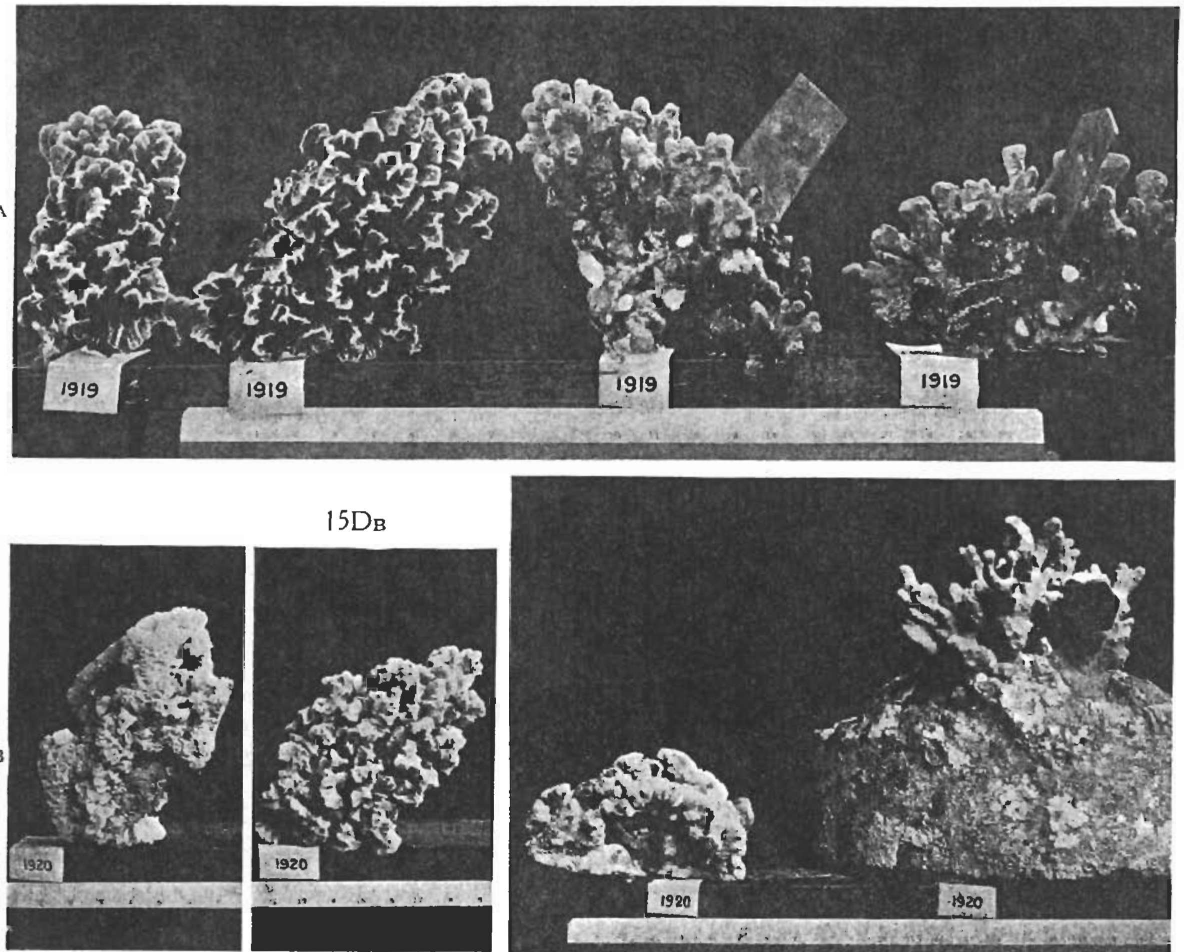
Fig. 8S.--Acropora (Tylopora) leptocyathus (Brook).

15DA 17SA

15SA 17DA

15DB

15SB 17DB

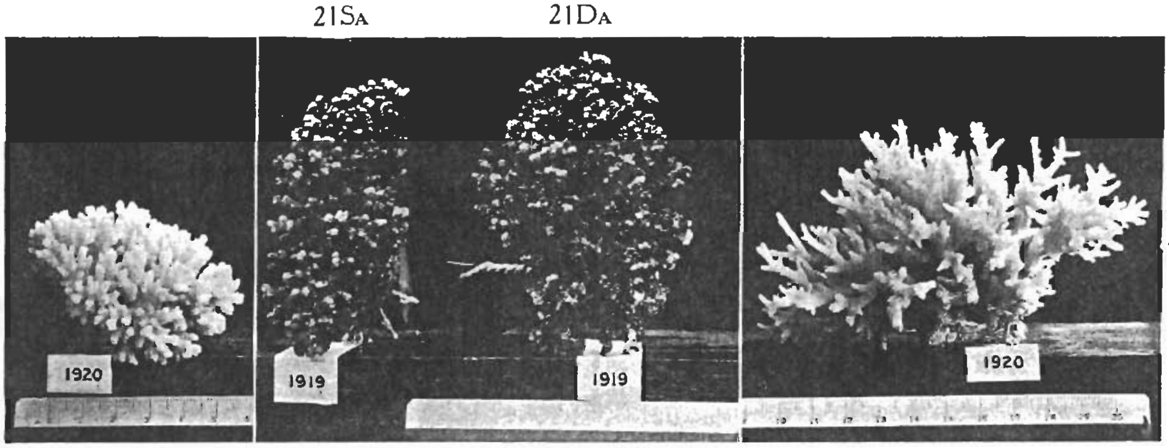


17SB

Figs. 15D, 15S.—Pavona divaricata Lamarck.
Figs. 17D, 17S.—Psammocora contigua var. maldivensis Gardiner.

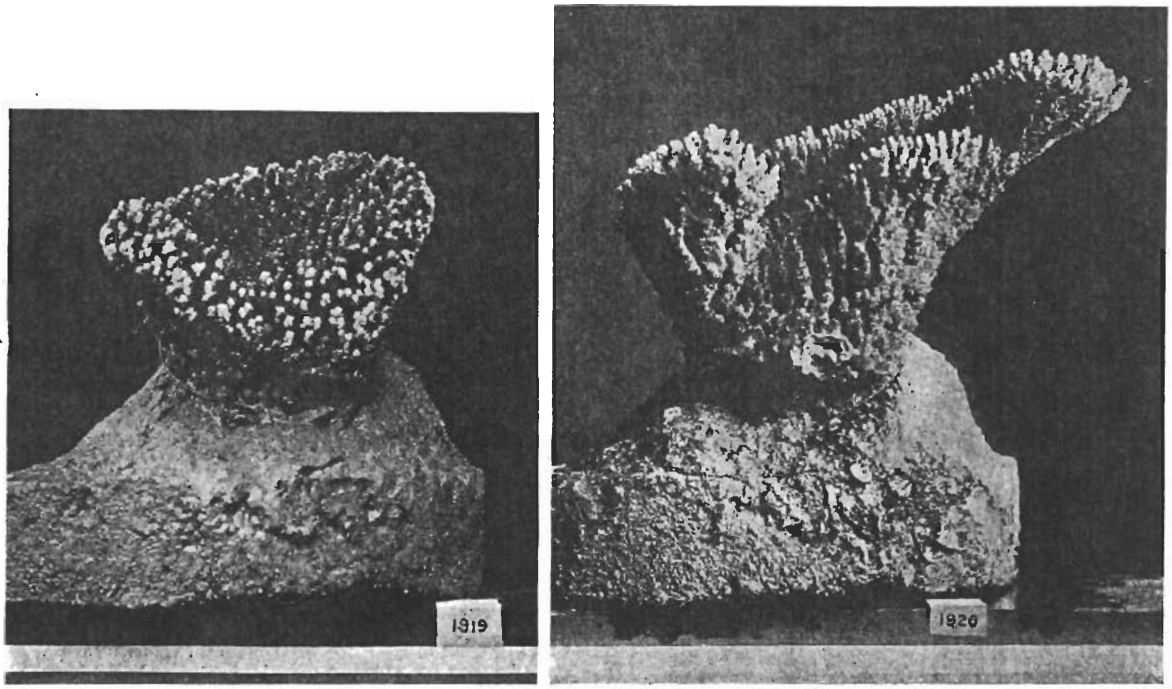
21SA 21DA

21SB 21DB



Figs. 21S, 21D.—Pocillopora damicornis var. cæspitosa Dana.

32DA



32DB

Fig. 32D.—Acropora hyacinthus (Dana).

24DA 24DB

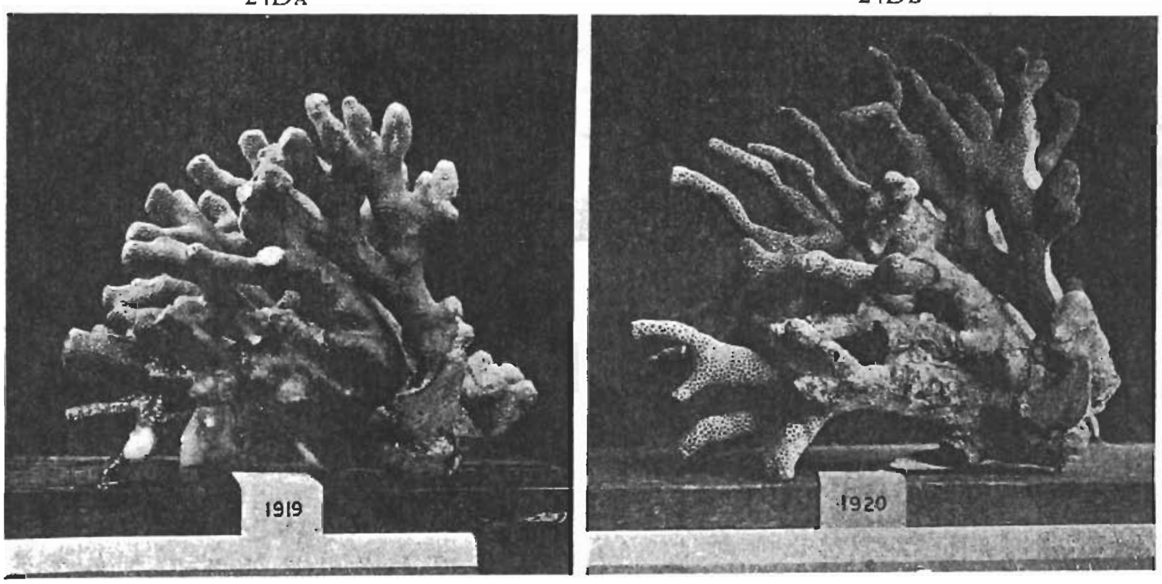


Fig. 24D.—Porites andrewsi Vaughan.

33DA 33DB

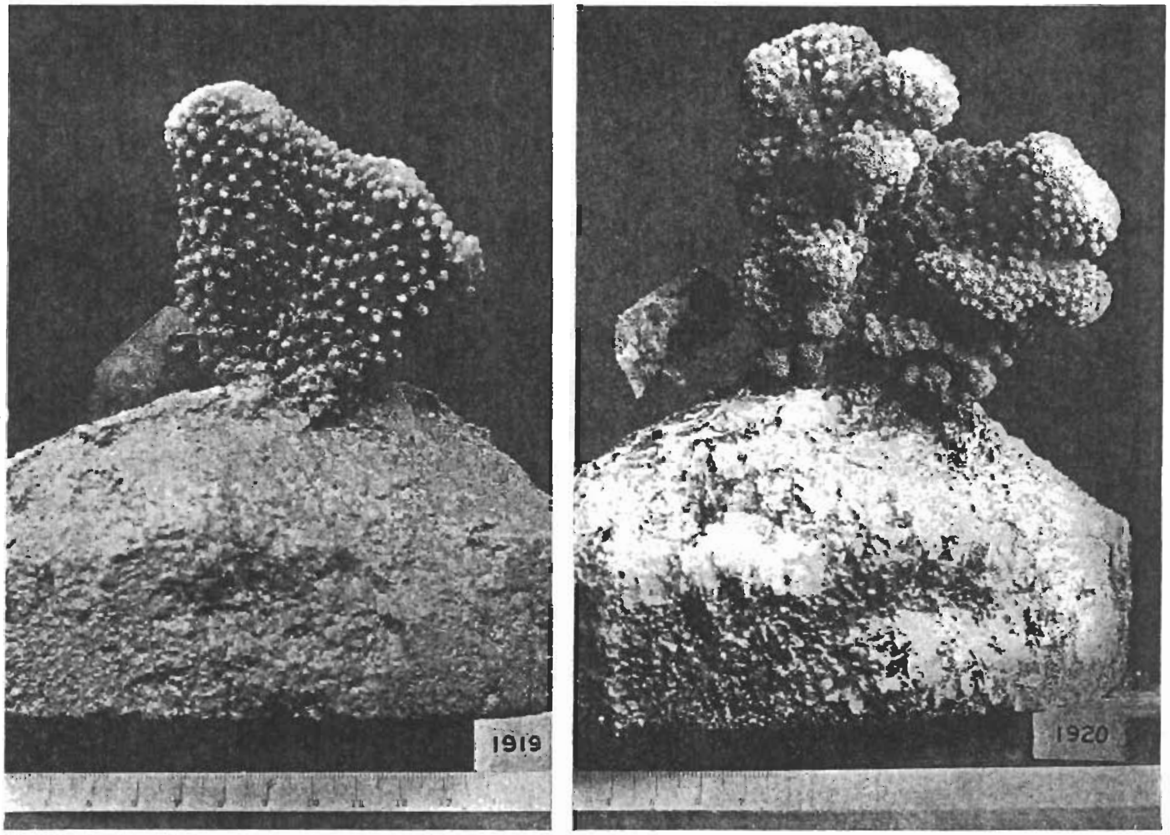


Fig. 33D.—Pocillopora eydouxi M. Ed. and Haime.

35DA 35DB

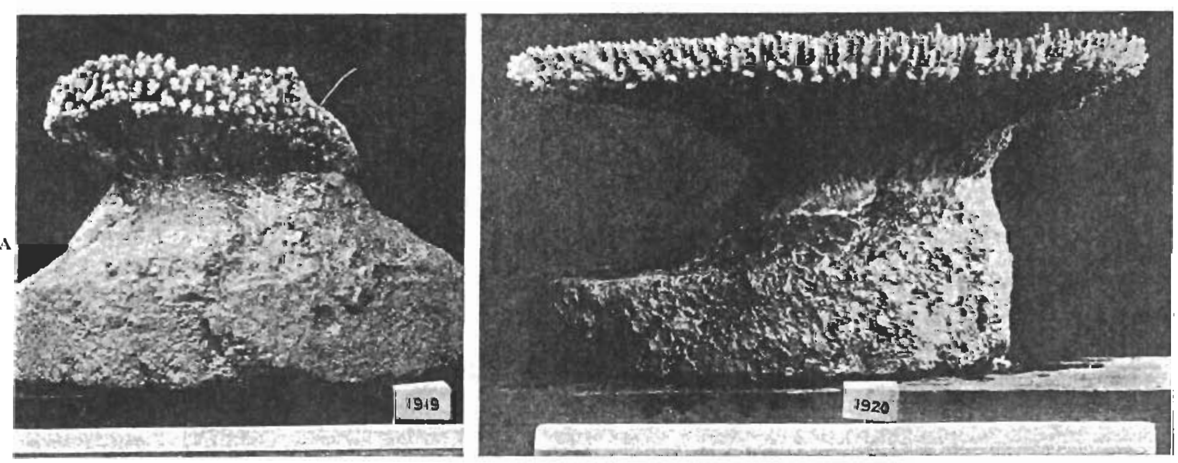


Fig. 35D.—Acropora hyacinthus (Dana).

35DB

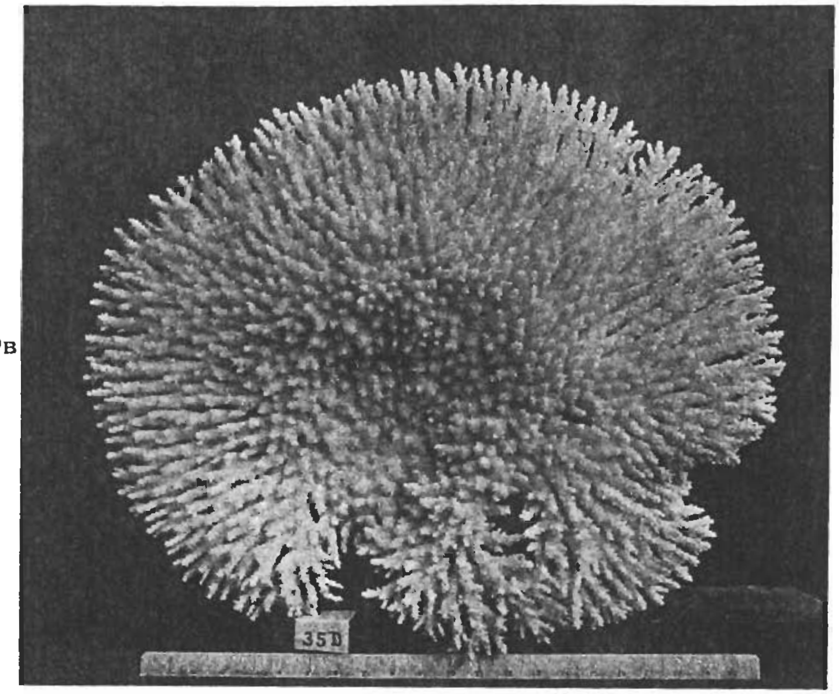


Fig. 35D.—Acropora hyacinthus (Dana). Top view.

36DA 36DB

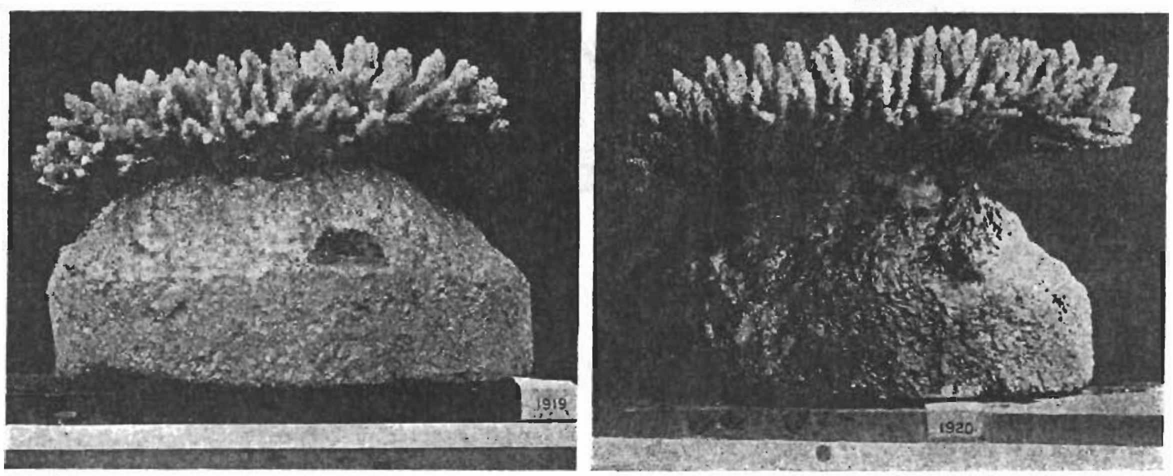
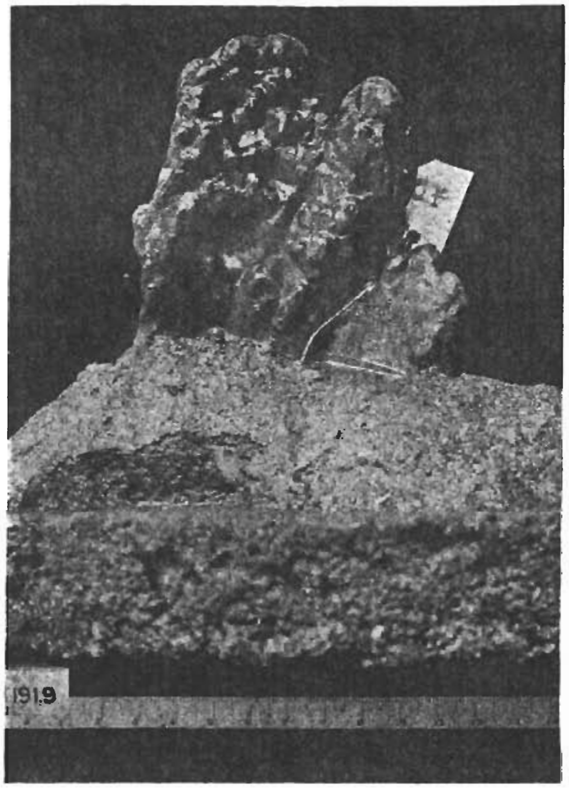


Fig. 36D.—Acropora cymbicyathus (Brook).

40DA



40DB

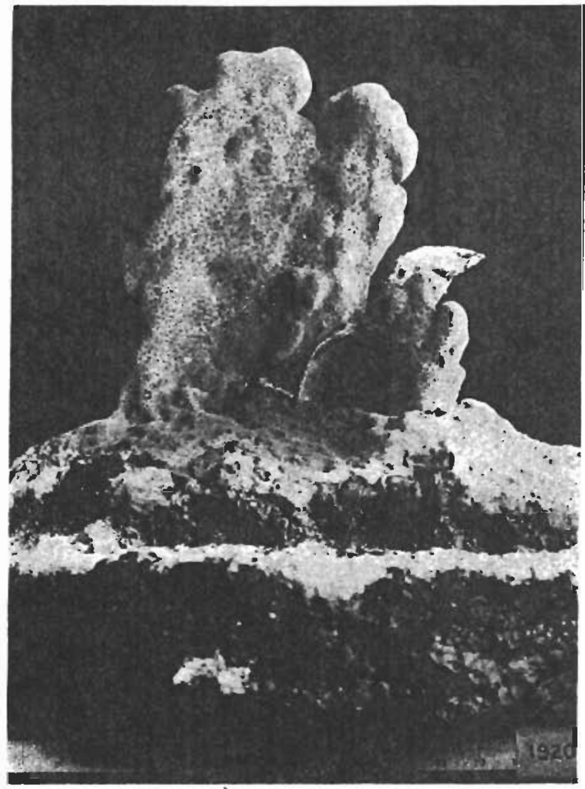
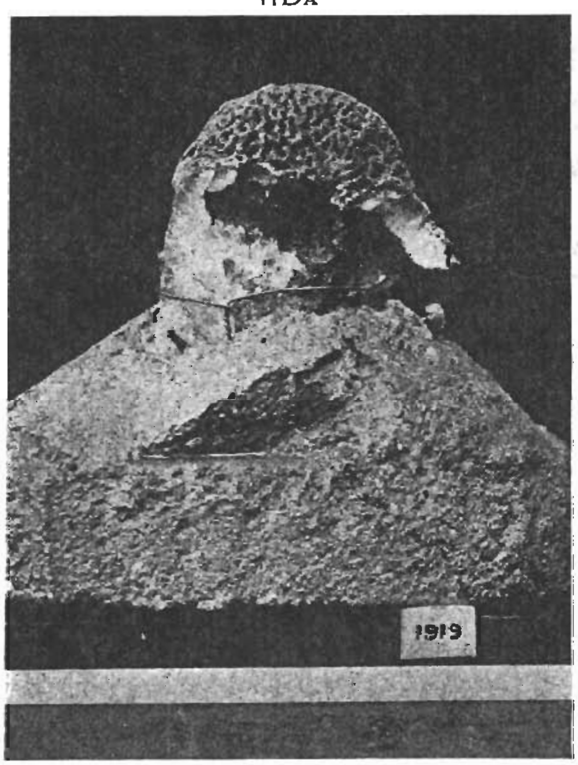


Fig. 40D.—Millepora truncata Dana.

41DA



41DB

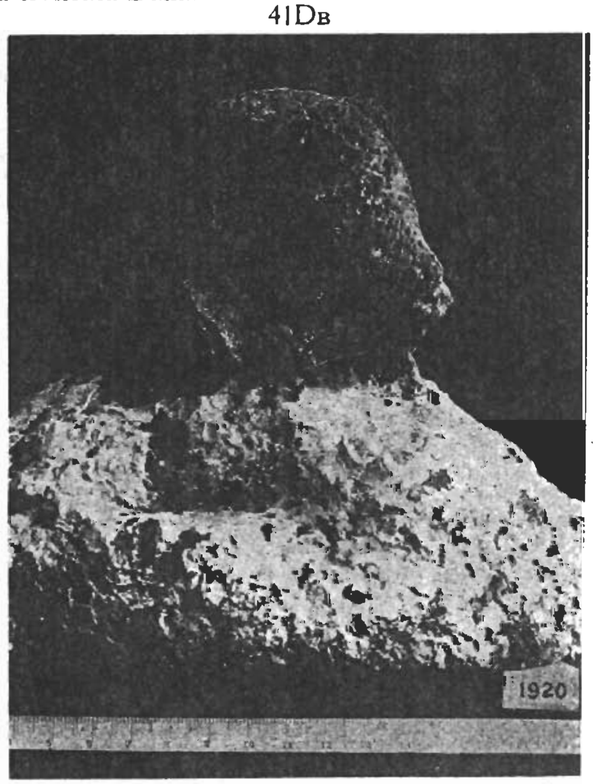
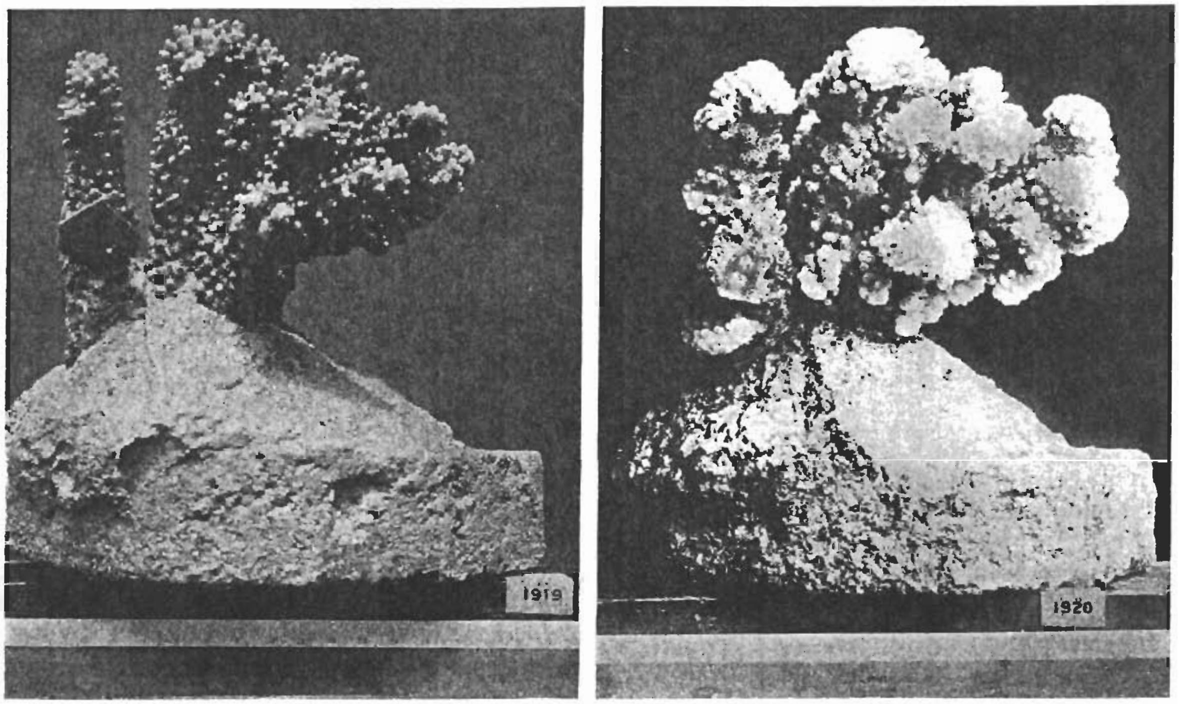
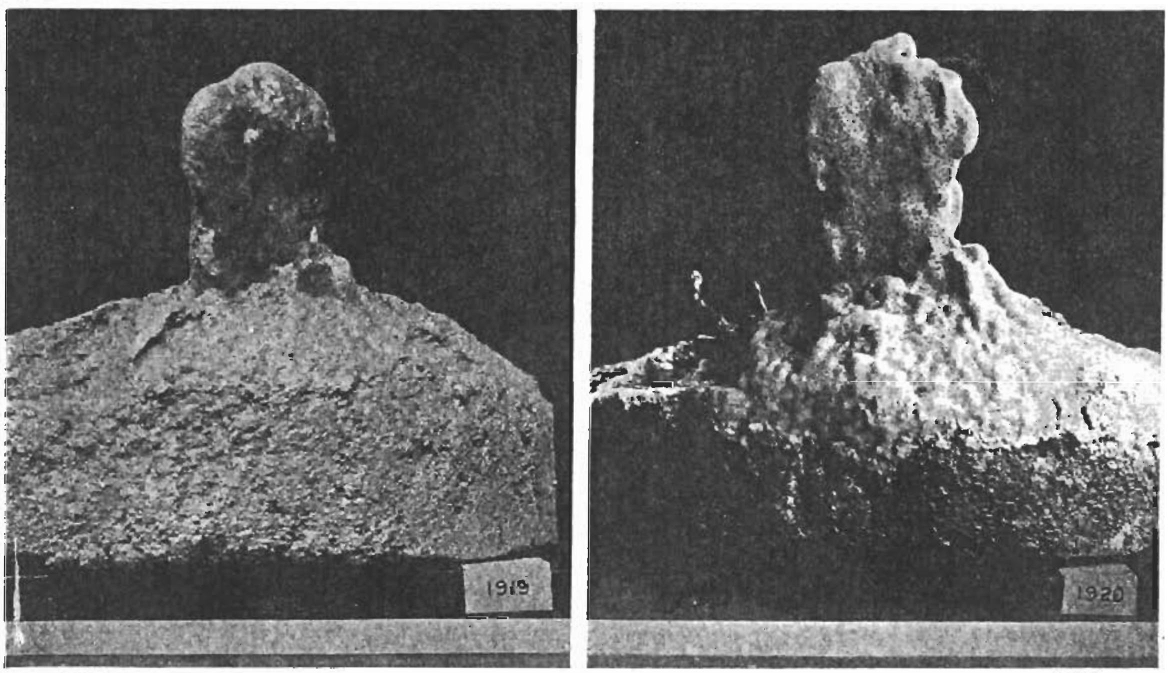


Fig. 41D.—Coscinaræa columna (Dana).



42DA 42DB

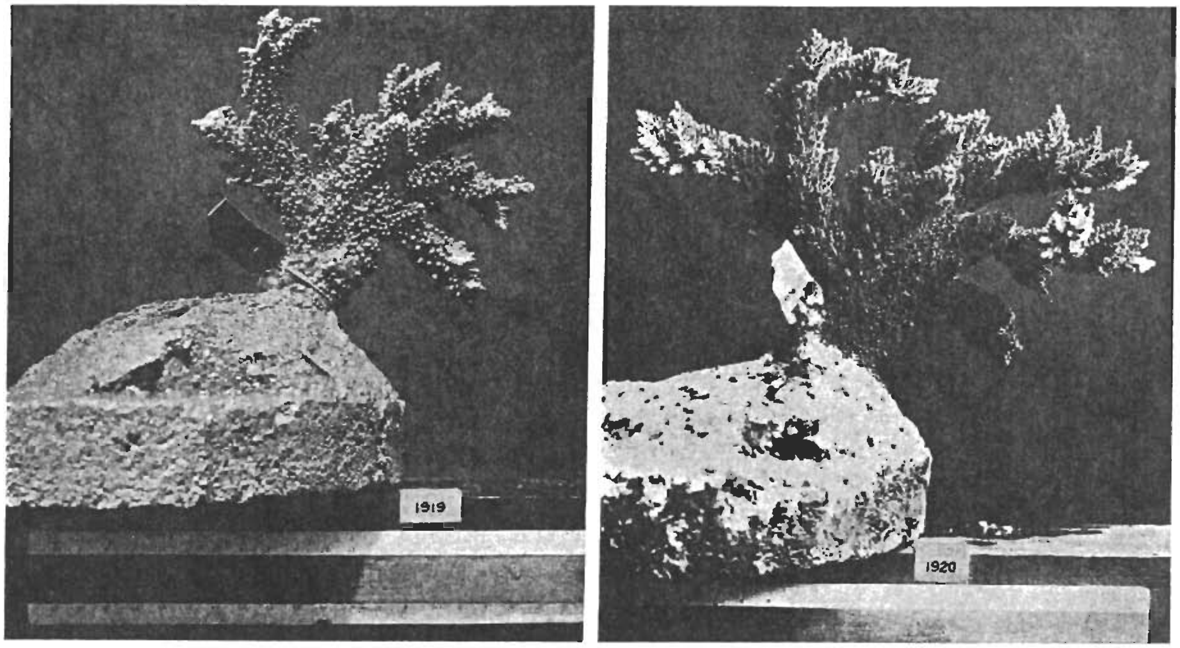
Fig. 42D.—Pocillopora eydouxi M. Ed. and H.



44DA 44DB

Fig. 44D.—Millepora truncata Dana.

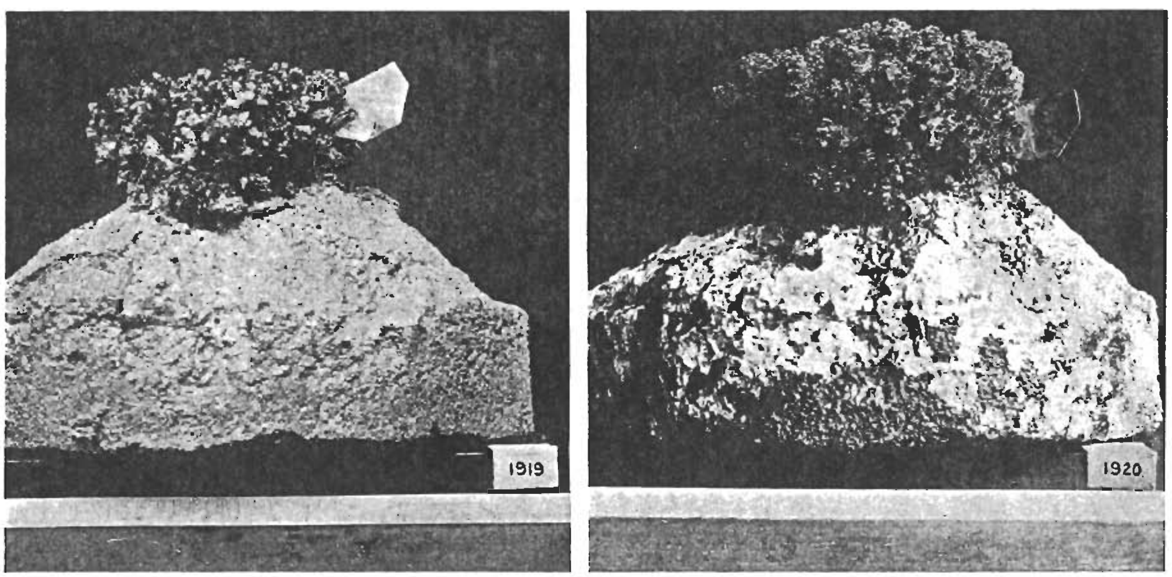
47DA



47DB

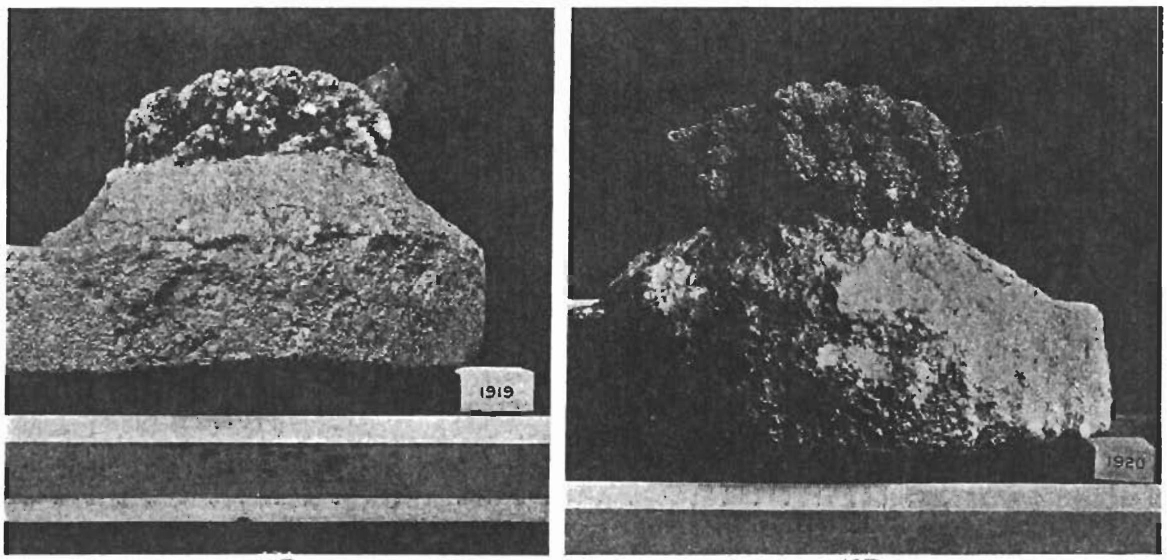
Fig. 47D.—Acropora tutuilensis, Hoffmeister.

45DA



45DB

Fig. 45D.—Pocillopora damicornis var. cespitosa Dana.



49DA 49DB

Fig. 49D.—Pocillopora brevicornis Lamarck.

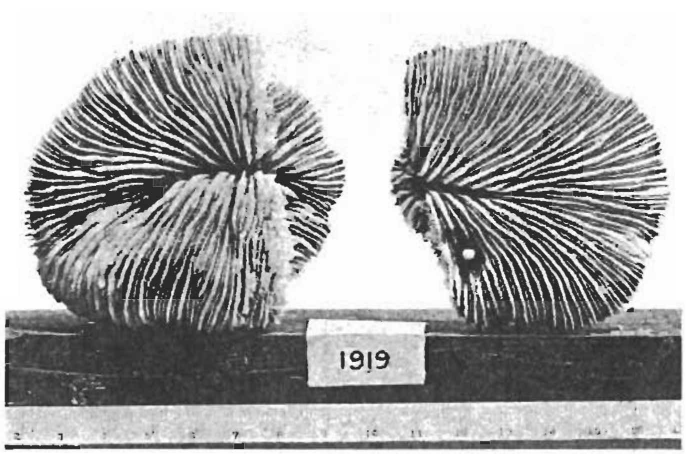
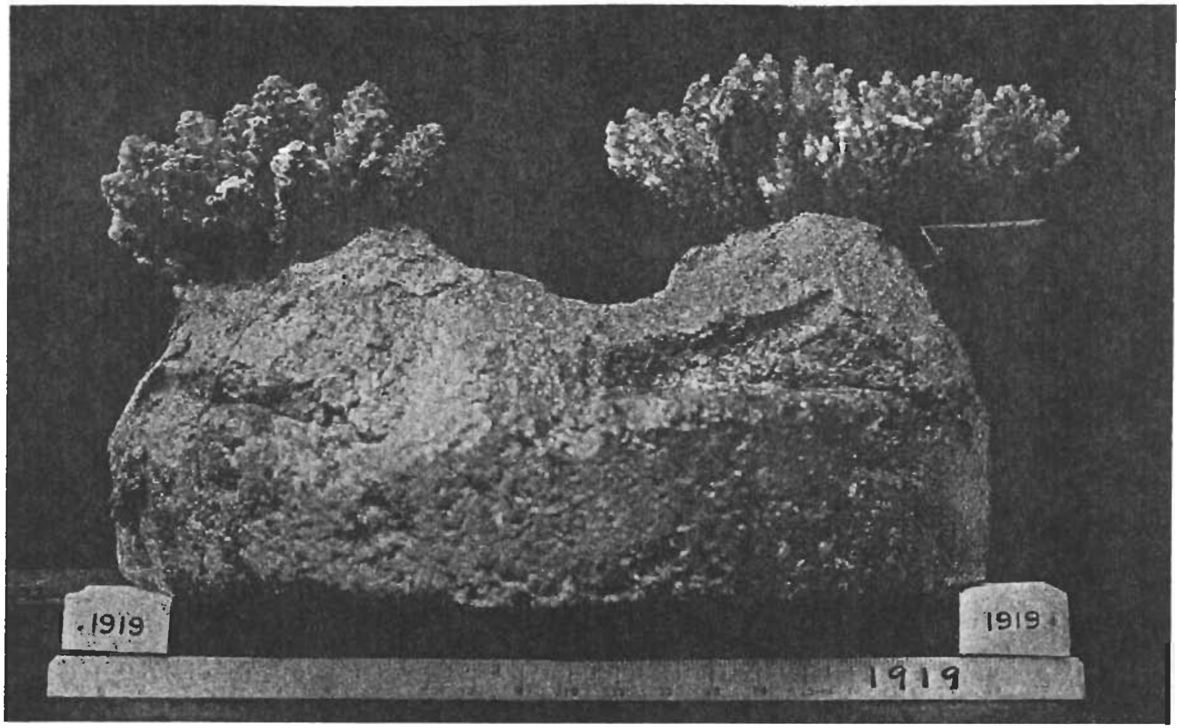


Fig. 64F.—Fungia paumotensis Stutchberry.

51DA 50DA



51DB 50DB

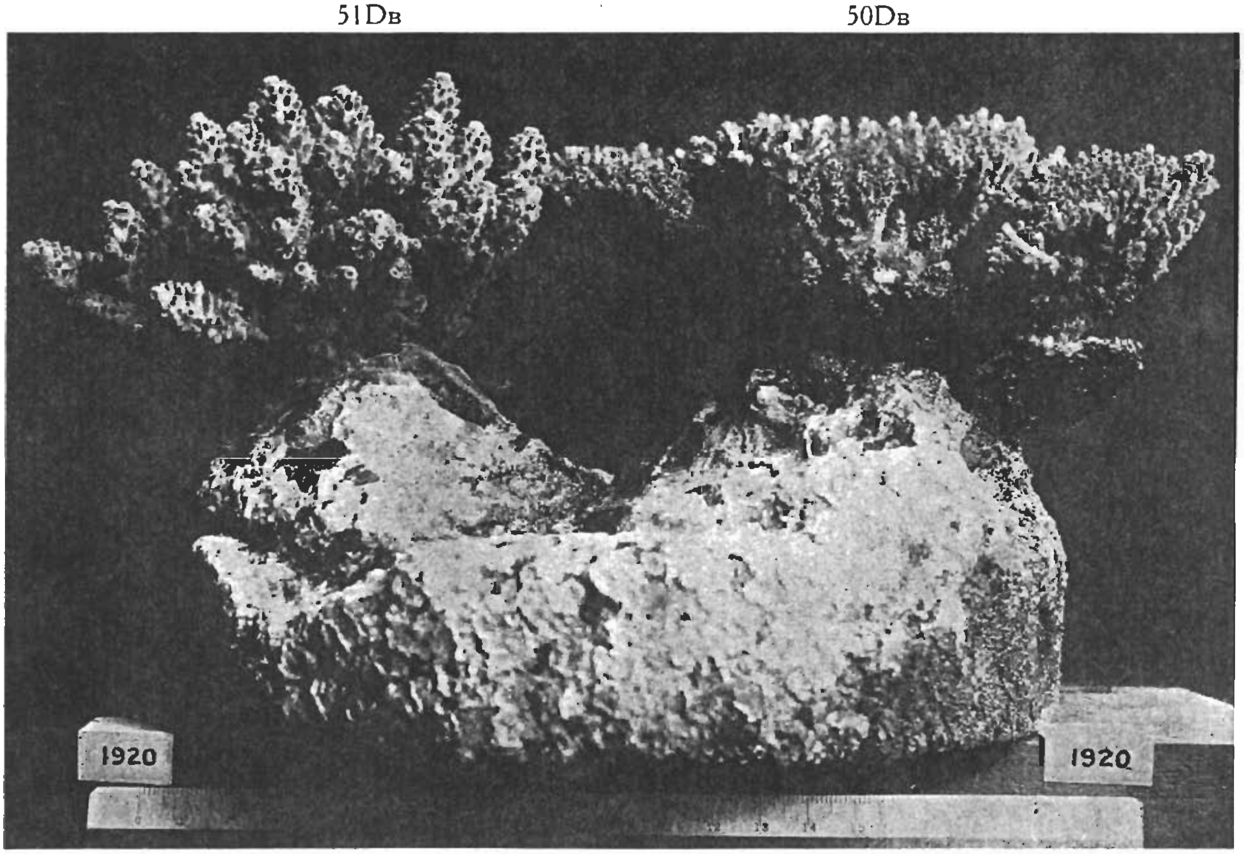


Fig. 50D.—Acropora hyacinthus (Dana).
Fig. 51D.—Acropora valida (Dana).