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REPRODUCTIVE BIOLOGY OF AN ALCYONACEAN CORAL, *LOBOPHYTUM CRASSUM* MARENZELLER

Kiyoshi Yamazato, Mayumi Sato and Hideyuki Yamashiro
Department of Biology, University of the Ryukyus, Nakagusuku, Okinawa, 901-24 Japan

ABSTRACT

The alcyonacean coral, *Lobophytum crassum* Marenzeller is one of the most common members of the coral reef communities in Okinawa. It is dioecious. Gonads are borne on all the mesenteries of a polyp except a pair of dorsal directives. Mature oocytes are large, up to 603.3 × 542.8 μm in diameter. Monthly mean number of oocytes per polyp varies between 52 and 138, with those reaching mature size in May and June being 36 per polyp. The breeding takes place in June, and fertilization appears to be external. The oocytes require two years for maturation, while only one year is needed for spermatogenesis. The polyps located in the periphery and on the tips of lobe-like projections of a colony are immature. The smallest gonad bearing colonies measure about 25 cm across. Their polyps contain only one-year old oocytes while those of the larger colonies have both one-year and two-year old oocytes.

Some of the above features are similar to those reported for another alcyonacean species, *Alcyonium digitatum*, by Hartnoll. However, the present species differs from the latter in having a prolonged period of oogenesis, a character which is shared with more remotely related species, such as *Corallium rubrum* and *Goniopora queenslandioe decima*.

INTRODUCTION

The alcyonaceans are important members of the reef flat communities in Okinawa. They come next to the stony corals in abundance in many localities. In some localities, they are even more abundant than the latter, particularly in the areas where the stony corals had been devastated by the predation of *Acanthaster planci* (Nishihira and Yamazato 1974). For this reason, knowledge of the biology of this group is important in the study of coral reefs.

As a part of more general studies on the biology of the Alcyonacea, the authors made some study on their reproduction. Among many species, *Lobophytum crassum* Marenzeller is the most abundant on the reef flat of Sesoko Island, where the Marine Science Laboratory of the University of the Ryukyus is located. For the sake of convenience, we have chosen this species as a representative of the Alcyonacea, and studied the specimens inhabiting the reef flat near the Marine Science Laboratory.

Very limited information had been available on the reproduction of the Alcyonacea, particularly on the Family Alcyoniidae, except the interesting studies made on *Alcyonium* by Hartnoll (1975, 1977). The present study presents some new features of alcyonacean reproduction, such as prolonged period of oogenesis.

MATERIALS AND METHODS

SEASONAL CHANGE IN THE GONAD SIZE

In order to study the reproductive season, five colonies of *L. crassum*, measuring about one meter in diameter were selected. This size is about the maximum attainable by this species on this location. From these colonies samples were collected once or twice a month for one year from April, 1979. A colony of *L. crassum* has a disk-shaped body supported by a stalk, with the disk bearing many lobe-like projections on the upper surface. The polyps are distributed over the surface of the disk and its lobe-like projections. They are completely contractible.

At each sampling, a fan-shaped piece measuring about 10 cm in radius and 5 cm in circumference were cut out of each colony, and preserved in alcohol for later study. Care was taken not to cut a piece from the side close to the previous cuts. It is assumed that the periphery of the disk and the tips of the lobes constitute the growth points for the colonies. If this is the case, the polyps located at these parts are expected to be immature. In order to exclude the immature polyps from sampling, the samples were taken from the middle portions of the lobes which are located reasonably far away from the periphery of the disk.

Five polyps were selected randomly from each sample piece, and all the oocytes contained in each polyp were transferred to a holed slide-glass. The longer and shorter diameters of each oocyte were measured by a micrometer under a binocular microscope. The size of oocyte was expressed in terms of the size index which is the product of the longer and shorter diameters. This treatment was necessary because the oocytes have distorted shapes due to fixation of contracted polyps. The data for five polyps were pooled together and the relative abundance of oocytes were plotted against the size-index classes for the monthly samples (Fig. 1).

The testes were examined in the same way as above, except that all the testes contained in several polyps were pooled together, and a hundred testes were randomly selected for size measurements. Their size was also expressed in terms of the size index. The seasonal changes in the size index of oocytes and testes are shown in Figure 2. In Figure 2 the oocytes are classified into three groups, 1st, 2nd and 3rd, according to their size, that is, large, medium and small, respectively. The mean numbers of the oocytes contained in a polyp are shown in Table 1.

DISTRIBUTION OF IMMATURE POLYPS WITHIN A COLONY

As suggested above, the periphery of the disk and the tips of the lobes may bear immature polyps. In order to test this assumption, a female colony measuring about 60 cm in diameter was collected on December 4, 1979. Eight lobes (a to h) are present on the disk along a line from the center to the periphery (Fig. 3). From each lobe, 30 polyps were collected along a line from the tip to the base. The number of immature polyps occurring within the upper, middle, and lower 10 polyps were counted. The size of oocytes contained in two polyps belonging to the intermediate groups of five lobes (a, c, e, g, h) were measured. The mean size indices thus obtained are shown in Figure 3.

COLONY SIZE AND MATURATION

In order to find out at which size this species starts to reproduce sexually, colonies with different sizes were collected on January 18 and February 1, 1981 (Table 2). They were treated in the same way as above, and the size of gonads were also expressed in terms of the size index. The sample colonies were also used for obtaining supplementary information as to the distribution of immature polyps over the colony lobes. The diameter of each colony was determined underwater.

RESULTS

SEX AND REPRODUCTIVE CYCLE

All of the colonies examined were either female or male. All polyps of one colony belong to the same sex and none showed any indication of sex change. The total numbers of colonies examined were 18, which can be classified as follows: 4 immature, 10 female, and 4 male colonies. This sample size is not big enough to draw any conclusion as to the sex ratio.

The results shown in Figures 1 and 2 show that both oocytes and sperms are released sometime between June 6 and June 30. None of the female polyps contained planulae in the coelenteron. This suggests that fertilization is external and that this species does not brood the larvae.

It can be observed from Figures 1 and 2 that, although spermatogenesis is completed within a year, a period of two years is required for oogenesis. The growth rate of oocytes is very low during the first year, but it increases in the second year, particularly after October. Since the observations were made under binocular microscope, the size of the earliest recognizable gonads was in the order of magnitude of 50 μm in diameter. If histological sections were prepared, smaller gonads could have been recognizable, and therefore, the initial stages of gonad formation could have been recognized sometime earlier than September.

GONAD STRUCTURE

There are two types of polyps in the colonies of *L. crassum*, the larger autozooids and the smaller siphonozooids (Fig. 3). The gonads are borne only on autozooids. The female polyps bear gonads on six out of eight mesenteries. A pair of mesenteries which lack gonads may be the dorsal (asulcal) directives (Hyman 1940).

When two size groups of oocytes are contained in a polyp, the smaller oocytes aggregate at the upper portion of the mesenteries, while the larger oocytes spread over the entire length of them. There are some evidences which show that when a virgin female polyp bears the oocytes for the first time, they first appear aggregated at the upper end of the mesenteries, soon spread over their entire length and then start to increase in size. However, it is not clear whether the oocytes are mobile within a mesentery or they become dispersed as a result of the upward growth of the mesenteries.

The number of oocytes contained in a polyp varies considerably (Table 1). Though not shown in Table 1, the range of actual number contained in a single polyp is from 26 (Jul. 30) to 163 (May 15). When the number of the oocytes are broken into different size groups, there appears a definite trend of change in the number as oogenesis proceeds. The number of oocytes are only 19 when they become first recognizable in September, and gradually increase to a maximum value of about 100 in May of the following year as the oocytes grow. Later on, the number of oocytes decreases to about 40 in September and maintain this level until June of the following year when the oocytes are released. During the first year,

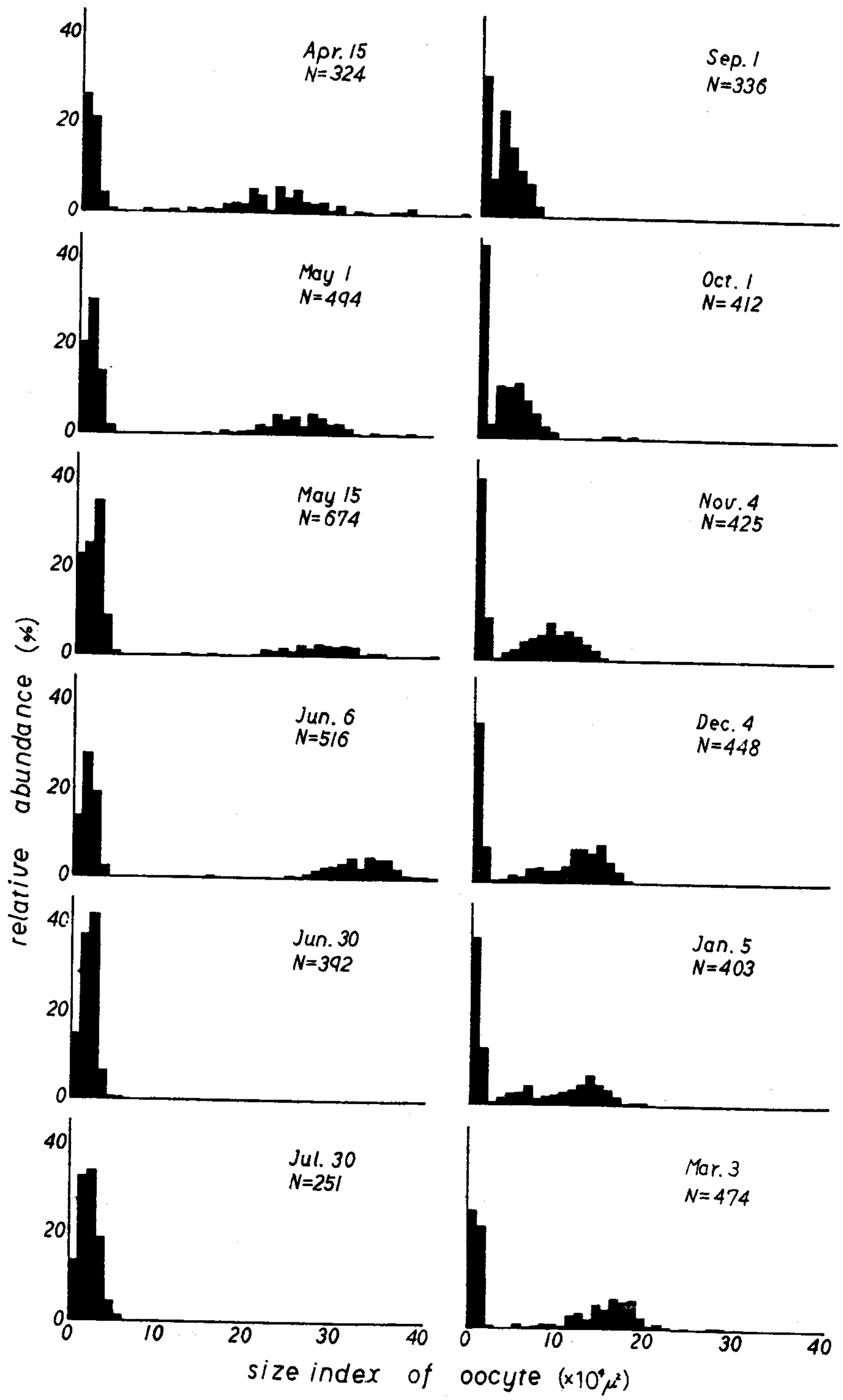

Figure 1. Seasonal changes in the size composition of oocyte in *Lobophytum crassum*.

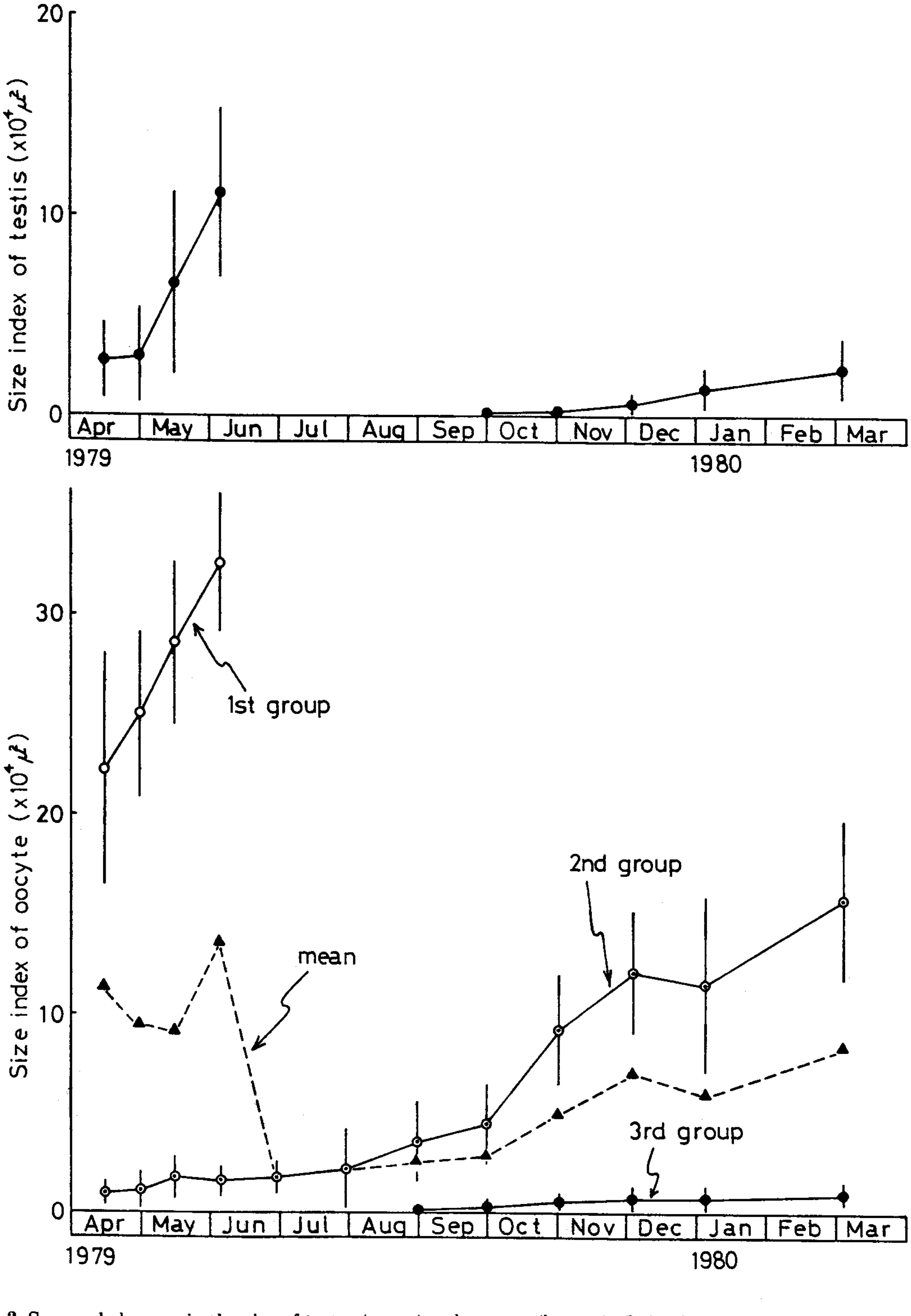

Figure 2. Seasonal changes in the size of testes (upper) and oocytes (lower) in *Lobophytum crassum*.

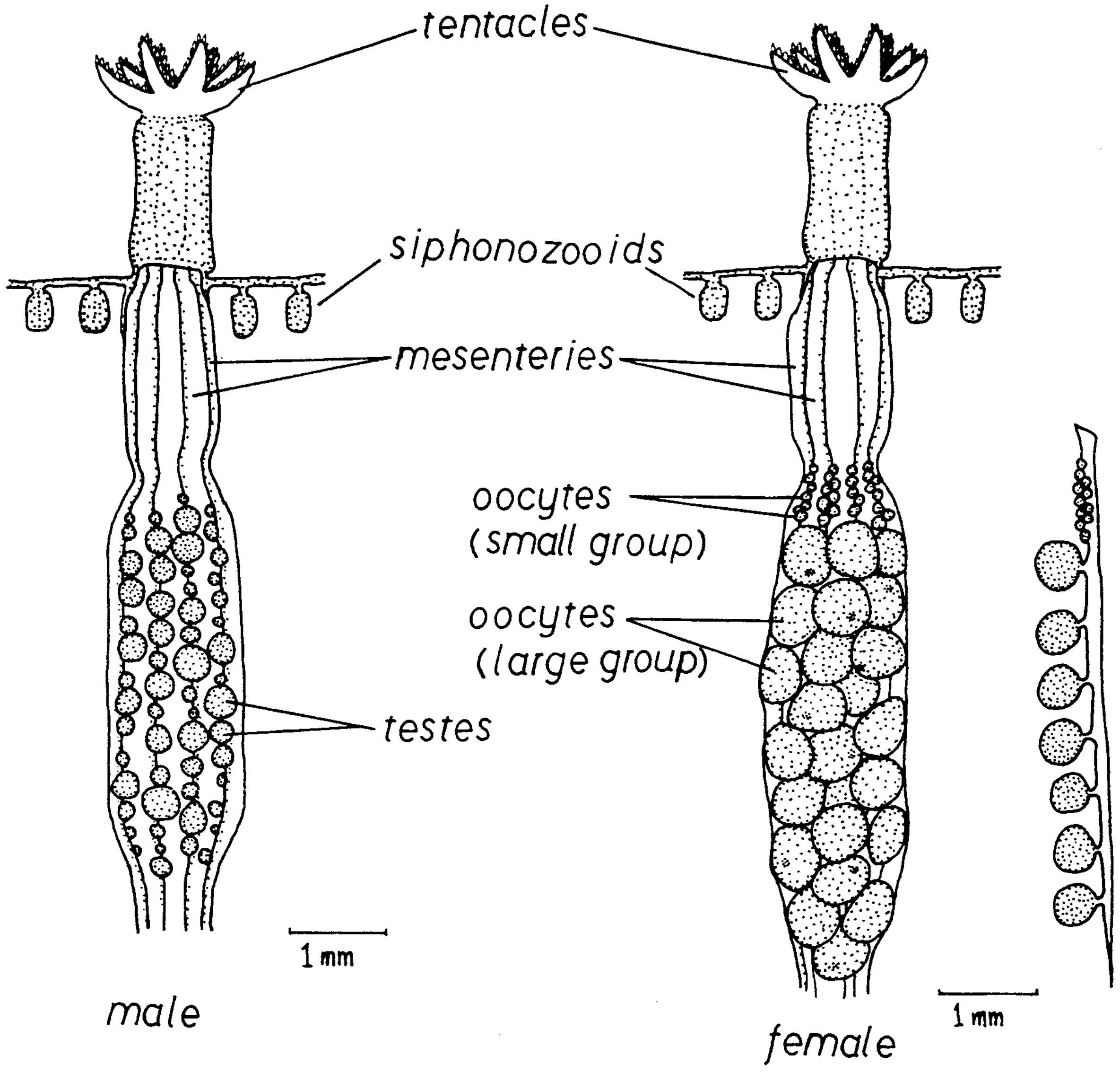

Figure 3. Diagrammatic illustration of the female and male polyps of *Lobophytum crassum*. An isolated mesentery with two size groups of oocytes is shown to the right of the female polyp.

Table 1. Seasonal changes in the number of oocytes contained in a polyp of *Lobophytum crassum*.

Date:	1979 4.1	5.1	5.15	6.6	6.30	7.30	9.1	10.1	11.4	12.4	1980 1.5	3.3
Oocyte												
3rd group	—	—	—	—	—	—	19	29	41	39	40	48
2nd group	33	64	104	64	78	52	43	39	44	49	41	47
1st group	32	33	34	42	—	—	—	—	—	—	—	—
Total:	65	97	138	106	78	52	62	68	85	88	81	95

Table 2. Colony size and reproductive status in *Lobophytum crassum* collected on January 18 and February 1, 1981.

Colony size (cm)		6	12	15	18	25	25	25	30	33	35	70	160	200
Wet weight (g)		8	51	79	83	—	—	—	—	—	—	—	—	—
Sex		I	I	I	I	♀	♀	♀	♀	♀	♂	♀	♀	♂
No. of oocyte per polyp	Small	—	—	—	—	14	23	12	21	29	—	32	45	—
	Large	—	—	—	—	—	—	—	—	24	—	52	40	—
Mean size-index of oocyte (X $10^4\mu^2$)	Small	—	—	—	—	1.6	1.2	1.0	0.5	0.7	—	0.5	0.9	—
	Large	—	—	—	—	—	—	—	—	16.1	—	10.9	14.9	—

the oocytes grow at a slow rate but proliferate rapidly, whereas in the second year they grow fast but cease to proliferate. The mature oocytes grow to a maximum size of 603.3 × 542.8 μm in diameter.

The polyps of the small colonies which may have produced the oocytes for the first time have also smaller number of oocytes, and the number increases as the colonies grow in size (Table 2).

DISTRIBUTION OF IMMATURE POLYPS WITHIN A COLONY

Two types of polyps were recognized in a female colony collected on December 20, 1979, those with two size groups of oocytes and those with only the smaller oocytes. The former polyps are regarded as mature and the latter immature. Among the eight lobes examined, the innermost two and the outermost three lobes contain immature polyps. Almost all of the upper ten polyps of the innermost two lobes were immature. All the polyps of the outermost lobe (Fig. 4h) and about half of the polyps of the next lobe (Fig. 4g) were immature.

The presence of many immature polyps at these parts indicates that new polyps are constantly formed there by asexual reproduction. Relatively large size of the oocytes contained in the lobes of the middle parts of the disk (Fig. 4e) reflects the fact that there are few immature polyps on these parts.

COLONY SIZE AND MATURATION

The colonies of *L. crassum,* whose size is less than 18 cm across and whose wet weight less than 83 grams have no recognizable gonads (Table 2). Those colonies ranging from 18 cm to 30 cm in diameter have oocytes belonging to the 3rd (small) group, whereas the larger colonies have both the 3rd and 2nd (medium) groups. Unfortunately, no study was made as to the relation between colony size and age in *L. crassum.* Although there is no significant change in the size of oocytes belonging to either of two groups, there is a definite trend of increase in the number of oocytes, particularly that of the small group, as the colony size increases.

DISCUSSION

The reproduction of *L. crassum* can be compared with that of two British species of *Alcyonium,* the most closely related soft coral whose reproduction has been studied in detail (Hartnoll 1975, 1977). *L. crassum* has several points in common with *Alcyonium digitatum.* In both species, sexes are separate, fertilization external, reproductive cycle annual, and the oocytes large. However, *L. crassum* differs from *A. digitatum* in having a prolonged period of oogenesis and in not having a quiescent period preceding ovulation. Presence of the quiescent period was regarded as an adaptation to avoid predation of ova by zooplankton. Hartnoll (1977) considers that zooplankton is less abundant in winter when *A. digitatum* releases the gametes. If this is the case, then the reproductive pattern shown by *L. crassum* can be regarded as more typical to this group of anthozoans. The other species, *A. hibernicum* has more specialized pattern of reproduction: parthenogenesis and internally developing benthic planulae. According to Hartnoll (1977), these are the adaptive characters related to small body size of this species, that is, the limited reproductive resources.

The prolonged period of oogenesis is a character which *L. crassum* shares with rather remotely related anthozoans, the Mediterranean red coral, *Corallium rubrum* (Vighi 1972) and the Okinawan scleractinian coral, *Goniopora queenslandioe decima* (Yamazato and Oshiro, unpublished). In both species, oogenesis requires two years, while spermatogenesis is completed within a year. Both species produce large oocytes, that is, 325 μm in diameter for *C. rubrum* and 665 μm for *G. queenslan-*

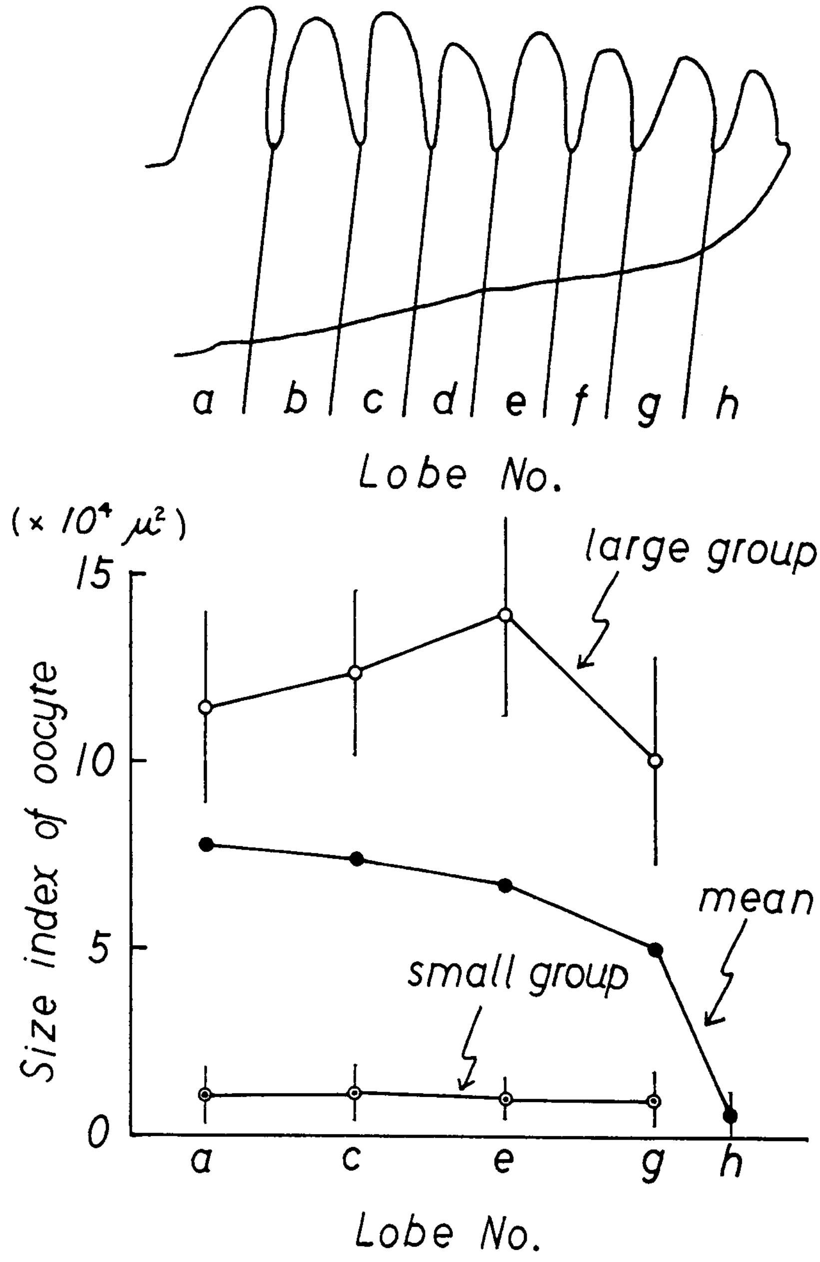

Figure 4. Changes in the size of oocyte from the interior to the periphery of a colony of *Lobophytum crassum* collected on December 4, 1979. The upper figure shows the arrangements of lobes on the disk.

dioe decima. For producing large ova, it may be advantageous or even necessary to spend such a long period as two years for oogenesis. Further study may add more species with such prolonged oogenetic periods.

As to the time of releasing gametes, there are three other reef invertebrates in Okinawa which breed during the same period as *L. crassum*, that is, the period from June to August. These are *Goniopora queenslandioe decima*, *Palythoa tuberculosa* (Yamazato et al. 1973), and *Acanthaster planci* (Yamazato and Kiyan 1973). Although there are other reef invertebrates which have different reproductive patterns, the above mentioned pattern could be regarded as one of the most common in the subtropical areas. The surface seawater temperature is kept above 25°C during the period from June to October in Okinawa. Temperature could be an important factor in controlling the timing of breeding (Yamazato and Kiyan 1973).

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