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GROWTH AND MORTALITY IN JUVENILE CORALS (*GONIASTREA, PLATYGYRA* AND *ACROPORA*) : THE FIRST YEAR

CROISSANCE ET MORTALITE CHEZ LES SCLERACTINIAIRES JUVENILES (*GONIASTREA, PLATYGYRA* ET *ACROPORA*) : LA PREMIERE ANNEE

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ABSTRACT

Past research on coral growth and mortality in the first year of life has been limited to species which brood their larvae. The larvae of three broadcast-spawning scleractinians, (Goniastrea aspera, Platygyra sinensis, Acropora millepora) were raised in sufficient numbers to obtain data on post-settlement growth and mortality. These are the first data on the growth of post-settlement stages (< 1 year) for non-planulating species.

Larvae were capable of settlement 3 to 4 days after spawning, at which time they were transferred to aquaria supplied with cut plates of coral. After settlement, these plates were deployed on reefs at Magnetic Island and at Orpheus Island. Zooxanthelae were not present in G. aspera or P. sinensis larvae, or in spat 5 days after settlement on the reef. After 10 days, juveniles of all three species contained zooxanthellae.

The growth rates of juvenile G. aspera, P. sinensis and A. millepora (1.5-6.8 mm mean diameter in the first year) are considerably slower than those of juveniles from planulating species (greater than 10 mm diameter).

The growth rates of G. aspera and P. sinensis were very similar, (1.6 and 1.4 mm diameter) while A. millepora (6.8 mm diameter) grew much more rapidly than either of the massive species. These growth rates are less than half those reported for the spat of planulating species of scleractinia.

Rates of mortality during the first year of life for scleractinian corals in situ are reported for the first time. Mortality of juveniles was calculated between the time of their first measurement (1-2 months old) and their most recent measurement (8-9 months old). The rate of mortality was similar for all three species, however the overall mortality of A. millepora (86%) was slightly higher than that of either of the two massive species, G. aspera (67%) and P. sinensis (73%) over the first 8 months of life.

RESUME

Les recherches sur la croissance et la mortalité des coraux pendant leur première année de vie ont jusqu'à maintenant été limitées aux espèces incubant leurs larves. Les larves de trois espèces émettant leurs produits sexuels (Goniastrea aspera, Platygyra sinensis, Acropora millepora) ont été élevées en nombre suffisant pour pouvoir fournir des données sur la croissance et la mortalité après fixation. Il s'agit des premières données obtenues sur la croissance des stades de moins d'un an, faisant suite à la fixation, pour des espèces ne relâchant pas de planulae.

Les larves sont capables de se fixer 3 à 4 jours après la ponte (émission des produits sexuels), moment auquel elles ont été transférées dans des aquariums contenant des surfaces de fixations constituées de surfaces (plaques) découpées dans des squelettes de coraux. Après fixation, ces plaques ont été installées sur les récifs de Magnetic Island et d'Orpheus Island. Les zooxanthelles ne sont pas présentes chez les larves de Goniastrea aspera de Platygyra sinensis, ou dans les stades post-métamorphose, 5 jours après fixation sur le récif. Après 10 jours, les juvéniles des trois espèces renferment des zooxanthelles.

Les taux de croissance des juvéniles de G. aspera, P. sinensis et A. millepora (diamètre moyen 1,5 - 6,8 mm pendant la première année) sont considérablement plus faibles que ceux des juvéniles des espèces relâchant des planulae (plus de 10 mm de diamètre).

Les taux de croissance de G. aspera et P. sinensis sont très voisins (1,6 et 1,4 mm de diamètre) tandis que A. millepora (6,8 mm de diamètre) grandit beaucoup plus rapidement que chacune des 2 espèces massives. Ces taux de croissances sont moins de la moitié de ceux qui ont été signalés pour les stades post-fixation des espèces de scléractiniaires relâchant des planula.

Pour la première fois, des taux de mortalité pendant la première année sont donnés, pour des scléractiniaires in situ. La mortalité des juvéniles est calculée entre le moment des premières mesures de taille (spécimens âgés de 1 à 2 mois) et la plus récente des mesures (spécimens âgés de 8 à 9 mois). Le taux de mortalité est comparable pour les 3 espèces. Toutefois, la mortalité totale de A. millepora (86 %) est légèrement supérieure à celle de chacune des deux espèces massives, G. aspera (67 %) et P. sinensis (73 %) pendant les huit premiers mois de vie.

INTRODUCTION

The post-settlement period, during which corals are also referred to as spat, is here defined as the period of time from larval attachment until the juvenile becomes visible to the naked eye. At present little is known about the duration or significance of the post-settlement period of hermatypic corals, despite the important role it is likely to play in the life histories of different coral species. In a number of previous studies, corals have been considered to recruit into the population only when they became visible (Connell 1973, Loya 1976, Bak and Engel 1979, Bothwell 1981) due to the difficulty of detecting spat in the field. Other studies have been carried out using settlement plates in order to provide data for corals during the post-settlement period (Birkeland 1977, Sammarco 1980. Birkeland et al.1981, Wallace and Bull 1981) and to compare visible and invisible recruitment (Rylaarsdam 1983, Wallace 1983, Rogers et al. 1984). These studies provided much useful information on general recruitment patterns but were limited by difficulties in identifying spat, especially at their earliest stages. In addition these techniques do not allow data to be obtained for a particular species starting from the time of settlement, a period during which corals are probably highly vulnerable to a variety of factors.

Previous reports on rates of growth and mortality of the post-settlement stages of scleractinian species have been limited to those corals which release planulae. Vaughan (1909, 1912, 1919) first measured in situ growth rates of newly settled Favia fragum and Porites astreoides by obtaining larvae from these species, allowing them to settle in aquaria, and then placing them back in the sea. Records from subsequent studies are sparse and are based on limited numbers of individuals e.g. 1 Cyphastrea ocellina (Edmondson 1929) and 1 Pocillopora damicornis, (Stephenson 1931, Reed 1971). Post settlement growth rates of Stylophora pistillata can be obtained indirectly from demographic information (Loya 1976), however these estimates are complicated by factors such as variability in both age and growth rate since S. pistillata releases planulae over a period of several months of the year, and nothing is known about the variability of early growth rates.

The only specific data on post-settlement mortality rates of hermatypic corals in the field are those of Vaughan (1912) for Porites astreoides, and Harriot (1983) for Pocillopora damicornis. Early growth and mortality rates have also been studied in situ for the ahermatypic Balanophyllia elegans (Fadlallah 1983) which releases large demersal planulae.

Of those species studied so far, all but the ahermatypic Balanophyllia elegans release planulae which contain zooxanthellae. In contrast there is no information on the early life history stages of the large number of scleractinian species which display the alternative behaviour of releasing eggs and sperm for external fertilization. Since the planulae of gamete spawning species are usually small and in most cases lack zooxanthellae when spawned (Heyward and Babcock 1985), post-settlement growth and mortality rates in these species might be expected to differ from those previously studied.

In order to obtain information on the growth and mortality of gamete-spawning corals, three species, Goniastrea aspera, Platygyra sinensis and Acropora millepora, were raised to settlement and returned to the reef. A simple and effective method for raising coral larvae is also presented along with data on the timing of zooxanthella infection.

MATERIALS AND METHODS

Study Sites: Work was done at two sites offshore from Townsville, on the Central Great Barrier Reef; Geoffrey Bay at Magnetic Island and Pioneer Bay at Orpheus Island. Goniastrea aspera, Platygyra sinensis and Acropora millepora are common on the reef flat of both bays at about the level of mean low water spring tides. Goniastrea aspera and P. sinensis were collected at Magnetic Island, and at Orpheus Island all three speices were collected.

Larval Culture Methods: Spawning times and dates were predicted on the basis of previous observations for these species (Babcock 1984, Harrison et al. 1984). Between two and five colonies of each species were placed in aquaria the day before the predicted date of spawning, and at least two colonies were always used to ensure cross-fertilization. Egg-sperm bundles were collected with a plastic squeeze bottle and poured into 4 litre plastic jars. 60 µm plankton mesh was placed over the mouth of the jars and the lids (the centres of which had been removed to allow exchange of water) were screwed down. The jars containing eggs and sperm were then attached to a buoyed line anchored in the sea where they remained at or just below the sea surface agitated by wave action. Larval cultures were examined daily to take samples and determine the developmental status of the larvae (Heyward and Babcock 1985).

Larval Settlement: When larvae began to achieve settlement competency they were transferred to aerated aquaria containing freshly cut and rinsed slabs of coral skeleton. The slabs were cut from either Porites, Favia or Platygyra, and were 8 cm square and 1 cm thick. After 8 to 10 days the majority of larvae in aquaria had metamorphosed and attached themselves to the slabs. They were then replaced in the sea so that the two main surfaces on each slab were vertical.

Juveniles of Goniastrea aspera and Platygyra sinensis were deployed at Magnetic Island, and Acropora millepora at Orpheus Island. Small numbers of G. aspera and P. sinensis were also placed on the reef at Orpheus Island. At both sites slabs were placed on the reef flat at approximately the level of mean low water spring tides. They were fixed by means of stainless steel rods through holes drilled in their centres. In the case of P. sinensis, some of the larvae which had settled inside their plastic culture jar were cut out and also placed on the reef at Magnetic Island.

Measurement of Juveniles: Newly settled corals were not counted prior to the deployment of slabs. Due to the cryptic nature of much of the settlement, especially on Favia and Platygyra, it was felt that such counts might be of questionable reliability. The slabs were examined at the following intervals: Goniastrea aspera and Platygyra sinensis 2.8, 5.1 and 7.8 months; Acropora millepora 3.4, 5.6 and 9.3 months. Platygyra on pieces of plastic were lost after the 2.8 month measurement. Coral slabs were recovered and held in aquaria for periods of two days to one week while they were being censused, since the newly settled corals were too small to be counted or measured in the field. Slabs were placed in seawater in small developing trays and examined using a dissecting microscope. All spat were counted, and measurements were made with a micrometer eyepiece. The largest diameter and the diameter at right angles to that were measured in order to obtain a mean diameter. Care was taken to record the dimensions of the skeleton, rather than the polyp. The skeletons of dead corals could be easily detected on the plastic jar with Platygyra spat, making a count of the original number of spat on the plastic possible. On coral slabs only live juveniles could be detected.

RESULTS

Zooxanthellae: The eggs of Goniastrea aspera, Platygyra sinensis and Acropora millepora lacked zooxanthellae at the time of their release, as did their larvae and newly settled polyps. Infestation with zooxanthellae apparently occurred between 5 and 10 days after settlement on the reef. Examination of 10 to 20 larvae of all three species prior to settlement failed to detect the presence of zooxanthellae either by examination of live material, histological sectioning, or fluorescent microscopy. Larvae began to settle inside the plastic culture jars during sampling 4.5-5 days after spawning. Five of the Goniastrea and Platygyra juveniles which had settled in aquaria also lacked zooxanthellae. Five days after resettlement on the reef Platygyra spat were sampled again and both live examination and fluorescent microscopy showed that no zooxanthellae were present. However, 10 days after resettlement on the reef all polyps of the three species were found to contain numerous zooxanthellae which were visible under a dissecting microscope.

Growth Rates: The growth rate of Acropora millepora (Fig. 1) was significantly greater than that of either Goniastrea aspera ($t=-33.2$, $p<.001$) or Platygyra sinensis ($t=-66.8$, $p<.001$). The mean diameter of A. millepora (5.1 mm) was approximately three times that of either favid species (1.3, 1.2 mm) at the time the latest measurements were made. There was no significant difference between the growth rates of G. aspera and P. sinensis ($t=.88$, $p>.2$). Variation in growth rate within a species could be quite large. For example A. millepora at 5.6 months old had a mean diameter of 4.1 mm (S.E. 0.48), however sizes ranged from as much as 8.8 mm diameter to as little as 1.2 mm.

Mortality Rates: Post-settlement stages of all three species suffered high mortality (Fig. 2).

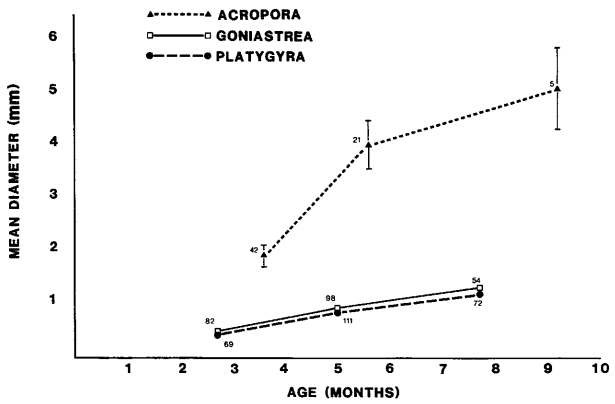

Figure 1. Growth rates of Acropora millepora, Goniastrea aspera and Platygyra sinensis. Bars represent standard error. (S.E. of G. aspera and P. sinensis means less than 0.1).

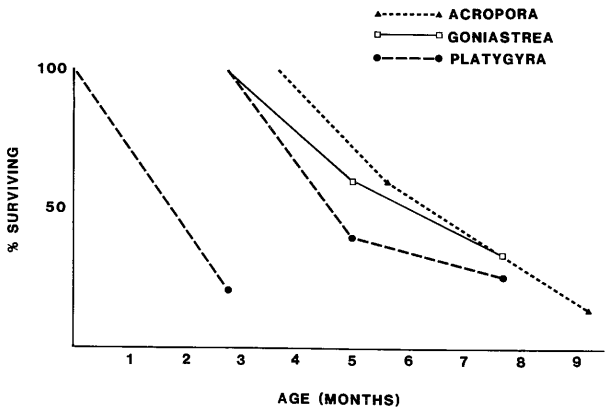

Figure 2. Mortality of Acropora millepora, Goniastrea aspera and Platygyra sinensis.

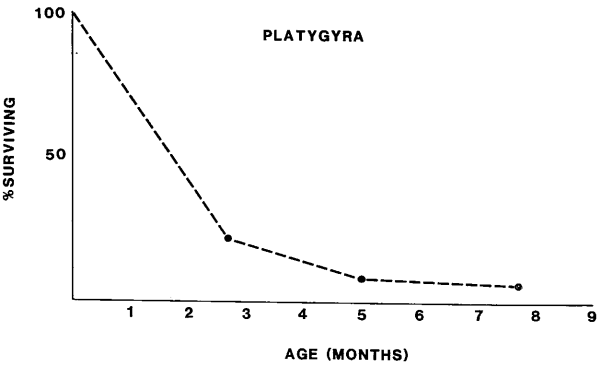

Figure 3. Composite mortality of Platygyra sinensis. 0 - 2.7 months: mortality on plastic fragments. 2.7 - 7.8 months: mortality on coral plates.

Acropora millepora had the highest rate of mortality. At the end of 9.3 months 86% of the sample population found on the slabs after 3.7 months had died. Mortality in juveniles of the two favid species was slightly lower. Between measurements at 2.7 months and 7.8 months old, 66% of the Goniastrea aspera, and 74% of the Platygyra sinensis had died. Analysis of living

and dead P. sinensis on the pieces of plastic jar after 2.7 months showed that 79% mortality of the newly settled juveniles had occurred during that period. The mortality data for P. sinensis surviving on plastic (0-2.7 months) and on coral slabs (2.7-7.8 months) were combined to produce a composite graph of survival for juveniles of this species (Fig. 3). The rate of mortality was highest in the initial period after settlement, and decreased during the subsequent months.

DISCUSSION

Despite the importance of zooxanthellae to the adult coral, larvae of Goniastrea aspera, Platygyra sinensis and Acropora millepora did not contain zooxanthellae until at least 5 days after settlement. Reinfection of tissues with zooxanthellae is necessary after the sexual stage in the life cycle of many invertebrates (Trench 1979). Some gamete spawning species of scleractinians (e.g. Montipora dilatata, Heyward in press) produce eggs which contain zooxanthellae prior to fertilization, and the larvae of hermatypic corals which brood their larvae contain zooxanthellae on release (e.g. Pocillopora damicornis Reed 1971, Stylophora pistillata Rinkevich and Loya 1979b). The uptake of zooxanthellae by Goniastrea, Platygyra and Acropora therefore occurs at a relatively late stage.

The growth rates of all three species were found to be considerably slower than those reported in the literature for the post-settlement stages of other species of scleractinians (Table 1). Similarly slow growth rates have also been shown by Wallace (1983) for natural recruits, however most of these could not be specifically identified. Thus studies based on visible recruitment must consider a wide range of growth rates and failure to do so in the past may have resulted in significant underestimation of age at recruitment (Connell 1973), which could have pronounced effects on demographic studies. Growth rates measured for Goniastrea aspera, Platygyra sinensis and Acropora millepora also revealed considerable intra-specific varition. It should be noted that these three species, as well as most of those reported by Wallace (1983 and pers. comm.) are broadcast spawners. All of the other corals in Table 1 are planulating species, two of which, Pocillopora damicornis and Stylophora pistillata have been described as opportunistic species (Connell 1973, Loya 1976). The relatively rapid growth rates of these two species are consistent with such suggestions.

Size dependent mortality is a feature of most coral populations at later growth stages (Connell 1973), and results here (Fig. 2) indicate tht this probably applies to the post-settlement stages of G. aspera, P. sinensis and A. millepora where the smaller younger corals had a higher rate of mortality. The mortality rates from around three to nine months of Acropora millepora, Goniastrea aspera and in particular Platygyra sinensis (Table 2) are comparable to that reported for Porites astreoides (Vaughan 1912). However, these estimates are likely to be low since they are based on initial examinations at about 3 months, at which time some mortality would already have taken place. Results from the Platygyra sinensis on plastic jar fragments indicate that initial this mortality is considerable. Corrected mortality for Platygyra may therefore approach 94%, which is appreciably more than that of Porites astreoides.

Table 1. Post-settlement growth of hermatypic corals.

Species	Mode of reproduction	Mean diameter(mm)	Age	Source of diameter estimates
Stylophora pistillata (Loya 1976)	planulates	13	1yr	derived from geometric mean radius data of 1st yr. size class. n=20
Pocillopora damicornis (Reed 1971)	planulates	11	3mo.	direct measurement lab reared. n=1
P.damicornis (Stephenson 1931)	planulates	5	3.5mo.	measured from fig. 5. grown on reef n=1
Porites astreoides (Vaughan 1919)	planulates	12	1yr.	direct measurement n=15
Favia fragum (Vaughan 1919)	planulates	12	1yr.	direct measurement n=30
Cyphastrea ocellina (Edmondson 1928)	planulates	3	3.5mo.	direct measurement n=1
Goniastrea aspera (this study)	spawns gametes	1.3	7.8mo.	direct measurement n=54
Platygyra sinensis (this study)	spawns gametes	1.2	7.8mo.	direct measurement n=72
Acropora millepora (this study)	spawns gametes	5.1	9.3mo.	direct measurement n=5

The mortality of Platygyra sinensis in the first three months is also much higher than that for Pocillopora damicornis over the same period on comparable (non-conditioned) substrate (Harriott 1983). Further experiments should be undertaken to determine whether the observations of high initial mortality and possible differences in mortality rates between planulating and non-planulating species indicated here are general features.

Previous attempts to raise coral larvae from eggs without agitation have been unsuccessful due to the buoyant nature of eggs and embryos (eg. Kojis and Quinn 1982). Successful development of eggs and larvae has been achieved previously by unidirectional mechanical agitation of eggs (Babcock 1984) however, despite the relative effectiveness of this method, considerable mortality was incurred due to the adherence of embryos to the sides of buckets. Multidirectional agitation in floating plastic jars used in the present study overcame this problem. In addition to being agitated, larvae were kept at ambient sea water temperature, and provided with a continuous exchange of fresh water. Results suggest that even more efficient water exchange could be achieved without loss of larvae by utilizing 100-150 µm plankton mesh when dealing with large eggs rather than the 60 m mesh used here. Up to 10,000 larvae were raised in each 4 litre jar in a healthy state, and capable of settlement after 4-5 days. This method shows great promise as a means of allowing research to be carried out in the areas of embryology, developmental rates, larval behaviour, genetics and distribution patterns of corals, as well as the aspects of population biology covered here.

Table 2. Post-settlement of hermatypic corals mortality.

Species	Time interval (months after settlement)	% Mortality
Platygyra sinensis	0 - 2.7	79
P. sinensis	2.7 - 7.8	74
P. sinensis	0 - 7.8	94
Goniastrea aspera	2.7 - 7.8	66
Acropora millepora	3.4 - 9.3	86
Porites astreoides (Vaughan 1912)	0 - 12	74
Pocillopora damicornis (Harriott 1983 bare blocks)	0 - 3	29

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REFERENCES

BABCOCK, R.C. (1984) Reproduction and distribution of two species of Goniastrea (Scleractinia) from the Great Barrier Reef Province. Coral Reefs. 2: 187-195.

BAK, R.P.M. and M.S. ENGEL. (1979) Distribution, abundance and survival of juvenile hermatypic corals (Scleractinia) and the importance of life history strategies in parent coral communities. Mar. Biol. 54: 341-352.

BIRKELAND, C. (1977) The importance of rate of biomass accumulation in early successional stages of benthic communities to the survival of coral recruits. In: D.L. Taylor, (ed). Proc. 3rd. Int. Symp. Coral Reefs. School of Mar. Atm. Sci., University of Miami. pp. 15-21.

BIRKELAND, C., D. ROWLEY, and R.H. RANDALL. (1981) Coral recruitment patterns at Guam. Proceedings of the Fourth International Coral Reef Symposium, Manilla 2: 339-344.

BOTHWELL, A.M. (1981) Fragmentation, a means of asexual reproduction and dispersal in the coral genus Acropora (Scleractinia: Astrocoeniida: Acroporidae) - A preliminary report. In Proceedings of the Fourth International Coral Reef Symposium, Manilla. 2: 137-144.

CONNELL, J.H. (1973) Population Ecology of Reef Building Corals. In: O.A. Jones and R. Endean (eds.) Biology and Geology of Coral Reefs. Vol. 2, Biology I. Academic Press, N.Y. pp. 204-245.

EDMONDSON, C.H. (1929) Growth of Hawaiian Corals. Bull. Bishop Mus. Honolulu. 58: 1-38.

FADLALLAH, Y.H. (1983) Population dynamics and life history of a solitary coral, Balanophyllia elegans from Central California. Oecologia, 5: 200-207.

HARRIOTT, V.J. (1983) Reproductive seasonality, settlement, and post-settlement mortality of Pocillopora damicornis (Linnaeus), at Lizard Island, Great Barrier Reef. Coral Reefs 2: 151-157.

HARRISON, P.L., R.C. BABCOCK, G.D. BULL, J.K. OLIVER, C.C. WALLACE and B.L. WILLIS. (1984) Mass spawning in tropical reef corals. Science 233: 1186-1189.

HEYWARD, A.J. (in press) Sexual reproduction in five species of the coral Montipora. In: Jokiel, P.L. and Richmond, R.H. (eds.) Coral Reef Population Biology, Hawaii Institute of Marine Biology Technical Report No. 37.

HEYWARD, A.J. and R.C. BABCOCK. (1985) Embryonic and post-embryonic development of some hermatypic scleractinians. 5th International Coral Reef Congress. Abstracts vol. p. 176.

KOJIS, B.L. and N.J. QUINN. (1982) Reproductive ecology of two faviid corals (Coelenterata, Scleractinia). Mar. Ecol. Prog. Ser. 8: 251-255.

LOYA, Y. (1976) Settlement, mortality, and recruitment of a Red Sea Scleractinian coral population. In: Mackie, G.O. (ed) Coelenterate Ecology and Behaviour, Plenum Press, New York. pp. 89-100.

REED, S.A. (1971) Techniques for raising the planular larvae and newly settled polyps of Pocillopora damicornis. In: H.M. Lenhoff, L. Muscatine and L.V. Davis (eds.) Experimental Coelenterate Biology. Univ. of Hawaii Press. pp. 64-76.

RINKEVICH, B. and Y. LOYA. (1979) The reproduction of the Red Sea coral Stylophora pistillata II. Synchronization in breeding and seasonality of planulae shedding. Mar. Ecol. Prog. Ser. 1: 145-152.

ROGERS, C.S.H., H.C. FITZ III, M. GILNACK, J. BEETS and J. HARDIN. (1984) Scleractinian coral recruitment patterns at Salt River submarine canyon, St. Croix, U.S. Virgin Islands. Coral Reefs 3: 69-76.

RYLAARSDAM, K.W. (1983) Life histories and abundance patterns of colonial corals on Jamaican Reefs. Mar. Ecol. Prog. Ser. 13: 249-260.

SAMMARCO, P.W. (1980) Diadema and its relationship to coral spat mortality: grazing, competition and biological disturbance. J. exp. mar. Biol. Ecol. 45: 245-272.

STEPHENSON, T.A. (1931) Development and formation of colonies in Pocillopora and Porites - Part I. Scient. Rep. Gt. Barrier Reef. Exped. 1982-1929. 3: 113-134.

TRENCH, R.K. (1979) The cell biology of plant-animal symbiosis. Ann. Rev. Plant Physiol. 30: 485-531.

VAUGHAN, T.W. (1909) Geology of the keys, the marine bottom deposits and recent corals of Southern Florida. Carneigi Inst. Wash. Yearbook. 8: 140-144.

VAUGHAN, T.W. (1912) Studies of the Geology and the Madreporaria of the Bahamas and of Southern Florida. Carnegie Inst. Wash. Yearbook. 11: 153-162.

VAUGHAN, T.W. (1919). Corals and the formation of Coral Reefs. Smithsonian Inst. Ann. Rep., pp. 189-238.

WALLACE, C.C. and G.D. BULL. (1981) Patterns of juvenile coral recruitment on a reef front during a spring-summer spawning period. Proc. of the Fourth International Coral Reef Symposium, Manilla. 2: 345-350.

WALLACE, C.C. (1983) Visible and invisible coral recruitment. In: Baker, J.T., Carter, R.M., Sammarco, P.W., Stark, K.P. (eds). Proceedings of the Great Barrier Reef Conference. J.C.U. Press. pp. 259-261.