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METHODS TO ENHANCE SEXUAL RECRUITMENT FOR RESTORATION OF DAMAGED REEFS

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ABSTRACT

Natural recruitment of scleractinian corals is highly influenced by various environmental effects. Predation, sedimentation, algal growth and grazing may cause high mortality rates in larvae and settlers. In the past, methods have been developed to produce large quantities of planulae. Under laboratory conditions the survival of ex situ produced propagules can be optimized to obtain large amounts of sexual recruits. Sexual recruitment plays an important role in conservation management, especially for the preservation of genetic diversity in natural and ex situ populations. We carried out pilot studies which indicate the possibility to transport, settle and recruit scleractinian corals, here *Acropora florida* Dana 1846, in closed-system aquaria using artificial seawater. After further development, this method promises to be an economical and effective way to mariculture corals for restoration of damaged reefs. To fulfill this aim, collaboration with commercial coral farms and public aquaria should be envisaged. Coral farms that provide work for coastal populations can play an important role in mariculturing sexual settlers. Such farms could produce thousands of propagules for reef conservation and even more for the aquarium trade thus reducing natural collection of corals and providing financial support by resulting incomes. Public aquaria may help to optimize this method.

In recent years, many studies have contributed to our understanding of the factors that influence coral recruitment. We will review in situ and ex situ gamete production, fertilization, settlement, and recruitment. Our own studies indicate the high potential of ex situ recruitment of sexual propagules for restoration management and the need of collaboration with coral farms and public aquaria for its realization in a larger scale.

Sexual recruitment depends on availability and survival of viable larvae, successful settlement, and early development of propagules (Richmond, 1997; Sorokin, 1995). In annual and multiple reproductive cycles millions of gametes or thousands of brooded planulae may be released by one coral colony. Broadcast-spawning species may produce 240 to 2880 eggs cm^2 yr^{-1}, brooding species 48 to 528 eggs cm^2 yr^{-1} (calculated after Szmant, 1986). Measurements of Shlesinger et al. (1998) ranged from 1000 to 3500 oocytes per polyp in the free-spawning family Mussidae. Fecundity is influenced by specific polyp and colony characteristics, like age, size, and mode of reproduction (Szmant, 1986; Harrison and Wallace, 1990; Sorokin, 1995; Shlesinger et al., 1998). In general, highest amounts of eggs are produced in free-spawning species with large polyps. Fecundity increases steadily with colony size throughout its life or in other words with the number of gravid polyps (Hughes et al., 1992; Orive, 1995; Hall and Hughes, 1996). In the genus *Acropora* with its typical large branches and its small polyps, species that do not reproduce asexually by fragmentation develop significantly more gametes than those that do (Wallace, 1985). Reproductive output is decreased by sub-lethal stress caused by several natural and anthropogenic factors, i.e., sedimentation, high temperatures, low tides, mechanical damage, pollution and eutrophication (Harrison and Wallace, 1990; Rinkevich, 1995). Coffroth and Lasker (1998) showed in the gorgonian, *Plexaura kuna* Lasker et al. 1996, that external fertilization rates of gonochoric, broadcast-spawners may be limited by the spatial distribution of male and female colonies. Dispersion of their gametes only

occurs over a range of a few meters in the water column. Fertilization success of brooding species may also depend on colony distance. Field manipulations with *Agaricia humilis* Verrill 1901 indicate a maximum distance of 2 m between colonies for successful sperm transmission (Morse et al., 1996).

Survival rates of free swimming gametes and planulae are difficult to estimate. Several attempts have been made to determine environmental sources which could decrease the amount of presettlement propagules. Westneat and Resing (1988) examined diet composition of planktivorous fish during mass-spawning events. Their results indicate high potential mortality rates of coral plankton. Brooded and broadcast-spawned planulae may remain for several weeks to months in the water column (Fadlallah, 1983; Wilson and Harrison, 1998). This increases the probability of encountering polluted water regions which may cause high mortality rates among coral propagules (Acevedo, 1991; Goh, 1991; Te, 1991; Richmond, 1997).

Successful settlement of planulae only occurs if several requirements are met. Settlement requires specific substrate type and orientation (Sato, 1985; Harriott and Fisk, 1987; Tomascik, 1991), biologically conditioned surfaces (Harrison and Wallace, 1990; Morse et al., 1994, 1996), water motion, salinity (Richmond, 1997), light intensity, and spectral quality (Babcock and Mundy, 1996; Mundy and Babcock, 1998). Eutrophication (Tomascik, 1991; Hunte and Wittenberg, 1992) and sedimentation (Sato, 1985; Hodgson, 1990; Babcock and Davies, 1991; Hunte and Wittenberg, 1992; Te, 1992) may reduce settlement directly and indirectly through algal growth which causes high mortality by itself and by incidental grazing by herbivores in the post-settlement phase (Sammarco, 1980; Sato, 1985; Sorokin, 1995). Other sessile organisms, like bryozoa and oysters which have high recruitment rates, decrease and limit survival of juvenile corals by spatial competition (Dunstan and Johnson, 1998). Moreover, hard and soft corals may inhibit settlement and survival of larvae and juvenile corals by negative interference (Maida et al., 1995; Atrigenio and Aliño, 1996; Fearon and Cameron, 1996,1997).

The mortality rate of juvenile corals during the first 3–12 mo of their life is between 60–90% (Sorokin, 1995). Thus, concerning all factors mentioned above a very low percentage of coral spat will recruit successfully in the reef and even fewer juvenile corals will obtain sexual maturity. If reefs are damaged or stressed, sexual recruitment and therefore genetic diversity might be drastically reduced. Ex situ cultivation methods can help to stabilize recruitment in disturbed environments.

Rinkevich (1995) supports the use of sexual and asexual recruits for restoration management. Sexual recruits may be produced in high amounts in the laboratory. Richmond and Jokiel (1984) obtained several thousands of planulae per month of the brooding species, *Pocillopora damicornis* Linnaeus 1758, by transporting adult colonies to the laboratory, placing them in containers, and collecting released larvae in a plankton net. Babcock and Heyward (1986) produced several hundred thousand planulae from several broadcast-spawning species by ex situ fertilization. Wilson and Harrison (1998) simplified this method. Several colonies were placed in aquaria prior to spawning. Spawned eggs and sperm bundles were collected at the surface of aquaria and incubated for 5–8 d until they developed into planulae. Szmant (1997) successfully obtained gametes for ex situ fertilization from the massive coral, *Montastrea* spp., by collecting gametes directly released in the field during the spawning event. Sperm concentration can be optimized to get high fertilization rates (Oliver and Babcock, 1992; Willis et al., 1997; Hatta pers. comm.) which can be used to produce high amounts of sexual recruits of brooding and broadcast-

spawning corals which might be cultured in aquaria until they passed the first, most critical year of life. Obviously, nearly all methods are already available to raise sexual propagules ex situ, but only few attempts have been made to do so. Those that have been done answer totally different questions like potential fitness loss of hybrids (Willis et al., 1997). No data concerning ex situ recruitment of sexual settlers have been published, nor has a direct comparison to natural recruitment been made. The lack of scientific facilities to maintain large amounts of scleractinian corals over a long period might be an important reason. The construction of these facilities is expensive and demands high financial input. New methods have to be applied for the development and management of strategies to restore damaged reefs if sexual recruitment is to be enhanced.

In modern public aquaria, stony corals like *Acropora* spp. may grow under sub-optimal conditions such as high-nutrient and low-pH seawater, with growth rates near the maximal rates reported from the field (Atkinson et al., 1995). Carlson (1987) reviewed the success of the cultivation of several coral reef organisms, including scleractinian corals, in captivity. Scleractinian corals are already successfully reproduced asexually and some brooding species have reproduced sexually in closed-system aquaria (Delbeek and Sprung, 1994; Tullock, 1997; Adey and Loveland, 1998). Under sheltered conditions of an aquarium settlement and recruitment of sexual propagules might be drastically increased. Willis et al. (1997) have been successfully culturing sexual recruits for more than 3.5 yrs in aquaria. The recruits are the result of ex situ self- and cross-fertilization experiments obtaining fertilization success up to 90%.

We carried out some pilot studies to develop methods to settle coral larvae in closed-system aquaria as a potential tool for reef restoration. We used *Acropora florida* Dana 1846 larvae derived from ex situ fertilization and hybridization experiments made by Masayuki Hatta in the marine lab in Okinawa (Japan). Larvae were sent via air mail to Munich (Germany). Our results indicate not only the feasibility of sending larvae over long distance, but also to settle and to raise propagules independently of coastal waters by the use of artificial seawater. Settlement and recruitment rates of sexual propagules were drastically increased compared to the natural environment. A further development of this method will be discussed, which could aid as a powerful tool to enhance sexual recruitment in damaged reefs. Special regards are given to economical aspects keeping developmental and running costs low.

Materials and Methods

Aquarium Facility.—The aquarium system was established in September 1997. The main tank (200 × 70 × 60 cm; illuminated with 2 × 250 W 20,000 K metal halide lamps 10 h d^{-1}, 2 × 36 W fluorescent lamps Osram Blue™ 12 h d^{-1}; 4 × 4000 L submersible impeller pumps for water motion) may be interchanged with several experimental tanks. Following the advice of Adey and Loveland (1998) and Delbeek and Sprung (1994), we maintained a microcosm in the main tank to improve water quality (water chemistry: salinity 38‰, Ca^{2+} 11 μmol L^{-1}, CO_3 8–10° dKH [German carbonate hardness], pH 8.1–8.27, NO_3 < 0.08 μmol L^{-1}, PO_4 0.03 μmol L^{-1}) which is in the range of natural conditions on coral reefs (see Sorokin, 1995; Adey and Loveland, 1998). To remove organic matter and toxins, a protein skimmer with a flow-through rate of 400 L h^{-1} was integrated, no additional mechanical filtration is used. Live rock (coral reef substrate containing all its associated organisms) acts as biological filter. Seawater is produced by mixing distilled water with commercial sea salts. Quality and sophistication of salt mixes have been greatly improved in recent years (Adey and Loveland, 1998). Consumption of essential elements especially of calcium and

carbonates is equalized by running a calcium reactor (uses carbon dioxide to dissolve aragonite sand; Delbeek and Sprung, 1994; Tullock, 1997) and adding commercial water additives. Minimal water changes (1–3% mo^{-1}) help to prevent salt drift. In this closed-system aquarium scleractinian corals are successfully maintained, even reproduced asexually by fragmentation (Acroporidae, Pocilloporidae, Poritidae, Agariciidae) and by parthenogenesis releasing planulae (*Pocillopora damicornis* Linnaeus 1758; Petersen, 1998). For general information on construction and management of natural closed-system aquaria see Carlson (1987), Delbeek and Sprung (1994), Tullock (1997) and Adey and Loveland (1998).

Settlement and Recruitment Experiments.—Mature colonies were collected around Okinawa and kept in seawater just prior to spawning. Spawning colonies were put in a bowl to collect eggs and sperm. From 100 to 500 eggs were released. These were washed twice in filtered seawater and mixed with 10^5 ml^{-1} of sperm in 50 ml vials within 3 h after spawning (Hatta, pers. comm.). After planulation, larvae were sent via air mail from Okinawa (Japan) to Munich (Germany). Transport took 3 d (2 transports: 06/22–06/25/98, 06/26–06/29/98). Between 50 and 200 planulae were transported, respectively, in complete darkness using several plastic vials without any additional protection against thermal influences during the transportation period.

Arriving planulae were immediately transferred into 2 L vessels and adapted to the water conditions in the aquarium by stepwise addition of aquarium water to a final volume of 1.5 L over the course of 2 h. Prior to the experiment, ceramic plates (∅4 × 0.5 cm) had been placed in the main tank of the aquarium system for a period of 5 wks to generate biologically conditioned surfaces. The tiles were self-made using pottery clay. The horizontal surface has been measured with approximately 14 cm^2, the vertical with 7.7 cm^2. We corrected for the surface ratio for statistical analysis. Each tile was removed from the aquarium and placed in a petri dish with 70 ml of aquarium seawater. Ten larvae were added to each of the petri dishes and incubated 2 wks at a temperature of 25°C (light intensity on water surface 5000–7000 lux, illumination 10 h d^{-1}; spectral quality was not measured). Settled and free swimming larvae were counted and juvenile polyps transferred to a cultivation tank (130 × 70 × 30 cm) which was connected with the main tank of the system. Light intensity had been carefully increased from 7000 to 38,000 lux (surface illumination between 8 to 12 h d^{-1}, spectral quality was not measured). Substrates were placed 15 cm under the surface on a polypropylene lattice without any fixation. Thus substrates could be removed easily for examination. Adequate water motion was provided by two submersible impeller pumps with an output of 2280 and 1000 L h^{-1} which produced an oscillating and powerful current to simulate natural conditions. Four fluorescent lamps (36 W, 2 × Osram Blue™ 12 h d^{-1}, 2 × Osram Daylight™ 10 h d^{-1}) and two metal halide lamps (150 W, 10,000 K, 8 h d^{-1}) generated intermediate light intensity.

Substrates were examined after 2, 7, 19, 32 and 40 wks under a microscope (20–30× magnification) to determine growth (number of polyps per colony) and survival rate. Eight month after the start of the experiment, the ceramic tiles with the juvenile colonies on their surface were transferred into the main tank and were fixed on rocks using underwater epoxy cement. Settling and survival rate between first and second transport and survival of horizontal and vertical settled propagules were compared using a chi-square test.

Results

Survival rates of *A. florida* Dana 1846 larvae delivered from Japan to Germany were 80 and 100%, respectively, for the first and second transport. Larvae were highly active, examining the vial by swimming and crawling. The first transport (arrival 06/25/98) contained 240 larvae of which 63 (26%) settled in petri dishes (55 on substrates, 8 on petri dishes) with a survival rate of 43% (settled + free-swimming propagules ÷ total number of larvae). The second transport (arrival 06/29/98) involved 160 larvae of which 59 (37%) settled (44 on substrates, 15 on petri dishes), measured survival rate was 53%. Survival

Table 1. Larval fitness expressed in settlement and survival rate. TL = Number of larvae of *Acropora florida*; CT/PD = Number of larvae settled on ceramic tiles/petri dishes; TS = Total number of settled larvae; FS = Free-swimming larvae; S1 = % Settlement; S2 = % Survival. Measurements were taken 2 wks after incubation.

Arrival date	TL	CT/PD	TS	FS	S1	S2

Rates that differ significantly between transports are indicated as * ($P < 0.05$)

and settling rate of the second transport was significantly higher (survival: $P = 0.001$; settlement: $P = 0.024$) (Table 1).

Only settlers (total of both transports) on ceramic plates were examined in further investigations. The percentage of surviving colonies (survived ÷ settled colonies) decreased from 82.8% (7th wk) to 71.7% (19th wk) and remained constant between the 32nd wk and the 40 th wk at 27.3%, when ceramic plates were fixed to the substrate (Fig. 1).

Vertically settled propagules survived significantly better ($P < 0.005$) compared to those that settled horizontally. From 53 colonies on the horizontal surface eight survived until the end of the experiment (40 th wk) compared to 19 surviving colonies of 46 colonies on the vertical surface (Fig. 2). At the last measuring date (32nd wk) total surviving rate of propagules (survived colonies ÷ total number of larvae) was 6.7%. After the 32nd wk all remaining colonies survived until the end of the experiment (40th wk).

Growth rate (number of polyps ÷ colony) varied highly among propagules but all of them approximated an exponential increase (Fig. 3). After 32 wks several colonies begun to develop branches thus it was not possible to estimate the exact number of polyps per colony thereafter.

Only one colony managed to obtain zooxanthellae during the first 2 wks of incubation in the petri dishes. However, in a short time after transfer to the cultivation tank, all settlers obtained their symbionts.

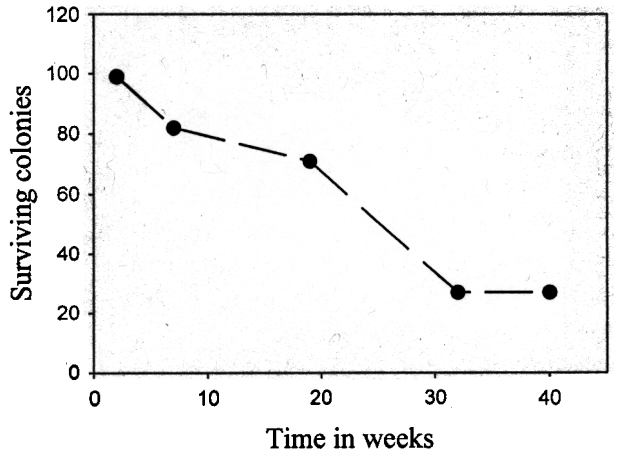

Figure Postsettlement mortality of *Acropora florida* Dana 1846 colonies on ceramic tiles.

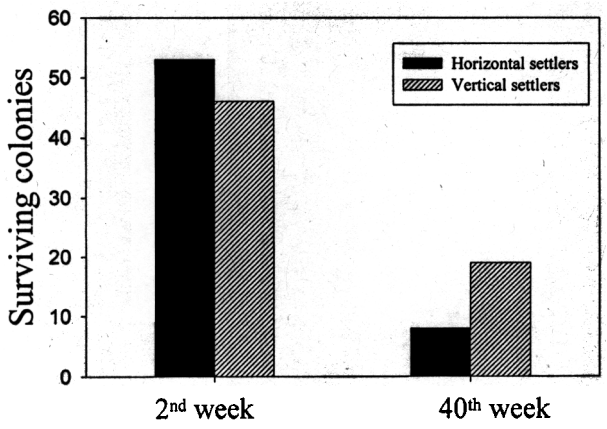

Figure 2. Survival of horizontally and vertically settled colonies of *Acropora florida* Dana 1846

Discussion

Settlement and Recruitment of Corals.—Our study demonstrates the possibility to settle and recruit coral propagules independently of their natural habitat. Ex situ settlement, growth, and recruitment rates are influenced by several factors.

Larval fitness expressed in survival and settlement rate was significantly higher in the second transport. Obviously transport conditions may influence larval viability. A difference of local temperature (1st transport: 25°C; 2nd transport: 32°C) at arrival may have contributed to fitness loss of larvae of the first transport, indicating the possibility of further optimization.

Larvae were settled under constant physical conditions: no variation in temperature, light quantity, or quality occurred. The recent work of Mundy and Babcock (1998) indicate complex species-specific responses to light conditions at settlement to optimize adult survival. Fadlallah (1983) mentioned temperature dependence of settlement rate in the brooding species *P. damicornis* Linnaeus 1758 around Hawaii that underlines the potential importance of temperature and light to increase settlement.

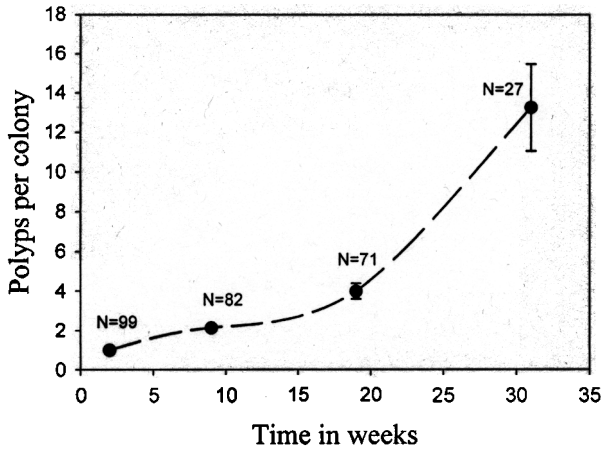

Figure 3. Growth of *Acropora florida* Dana 1846 after settlement, measured as number of polyps per colony, means ± 1 SE (n = number of colonies).

Comparing settlement between the conditioned ceramic substrates (81%) and the rather sterile surface of petri dishes (19%), the use of biologically conditioned ceramic tiles was preferred by larvae. This is in accordance with Harriott and Fisk (1987), who compared petri dishes and ceramic tiles among various settlement plate types and found ceramic to be the best substrate. Morse and Morse (1991) isolated a morphogen required by *Agaricia humilis* Verrill 1901 larvae for successful settlement. Morse et al. (1996) observed similar, algal-specific chemosensory mechanisms in several species among the most common genera of the families Acroporidae and Faviidae. In our study, those coralline red algae which are essential for *A. florida* settlement were presumably present in the aquarium microcosm in which the substrates had been incubated.

Shape and orientation of substrates can probably influence settlement and recruitment rate. *A. florida* Dana 1846 had a much higher survival rate when settled vertically in this study. Rates in the field are also highest on vertical or downward substrates because of algal growth, grazing and sedimentation (Sato, 1985; Harriott and Fisk, 1987; Tomascik, 1991; Hunte and Wittenberg, 1992). Richmond (1997) mentions a possible trade-off between settlement on vertical and horizontal surfaces. Corals settling on vertical substrates are more likely to survive while individuals settling horizontal attain higher growth rates. These facts conflict with the results of Sato (1985) who showed a direct correlation between survival and growth rate. Babcock and Mundy (1996) found high mortality rates on highly sedimented upper surfaces in the first few months after settlement, but in the following 5 mo highest growth and survivorship on the same surfaces. Cryptic, grazing-protected areas increase survival of propagules (Sammarco, 1980; Babcock and Mundy, 1996). Settlement choice may depend on species-specific attributes (Babcock and Mundy, 1996). In general, settlement, survivorship and growth possibly can be increased by hanging substrates vertically into the system and by changing the orientation after a certain colony size has been reached.

In this study, the survival rate of young settlers was probably decreased in the first twenty weeks due to several physical and biological influences. Ceramic plates were not fixed on the lattice and strong water movement caused drifting, rubbing and turning over of substrates. Resulting mechanical damage and decrease in light intensity by shading may have reduced growth and survival. Due to lack of grazing organisms in the cultivation tank, some growth of filamentous algae occurred on horizontal surfaces representing another source of mortality among the juvenile corals.

In nature, optimal conditions for survival of propagules seem to be given by moderate grazing (Sammarco, 1980; Sorokin, 1995). To simulate similar conditions, 50–100 small herbivorous snails of the genus *Stomatella*, which reproduced sexually in the aquarium-system, and three surgeon fishes (*Zebrasoma desjardini, Z. xanthurum*) were transferred to the cultivation tank. Algal turf was reduced without any visible injuries to corals. Larger herbivorous snails and fishes or even sea-urchins like *Diadema antillarium* (Sammarco, 1980) might depress coral recruitment greatly. Thus addition of small or selective grazers can facilitate survivorship in early colony stages.

Obtaining symbiotic zooxanthellae might represent another potential problem for coral recruits. *Acropora* spp. obtain symbiotic zooxanthellae from external sources in the first two weeks after settlement (Richmond, 1997). The work of Rowan and Powers (1991) raises the question whether there are species-specific correlations between algae and host. In that case, success might be limited by the lack of the right type of symbionts. However, in our aquarium symbionts for *A. florida* must have been provided by other *Acropora*

species which have been collected elsewhere. In fact, neither corals from around Japan, nor adult individuals of *A. florida* had been maintained previously, or were being maintained in the system.

PERSPECTIVES FOR RESTORATION OF DAMAGED REEFS.—To improve ex situ settlement and recruitment of sexual propagules more investigations will be necessary. Cultivation conditions might be optimized using a larger protein skimmer, effective grazing species and specially shaped ceramic plates which might be easily and reversibly fixed to the lattice and later to the reef. Studies of species-specific settlement patterns should be conducted to increase settlement on plates. If larvae have to be transported over long distances (between marine labs, coral farms or public aquaria) transportation conditions might be improved to obtain high survival of larvae. In the near future, techniques should be developed for deep-freezing gametes, so we can work independently of any natural reproductive cycle. Ex situ fertilization of broadcast-spawning species has been already well established, exceeding 90% and more (Oliver and Babcock, 1992; Willis et al., 1997; Hatta pers. comm.).

The next step will be to test the results of this study and possible improvements mentioned above in a larger scale. Direct comparison of sexual recruitment rates can be achieved through the design of experiments which combine studies in nature with those in closed- and open-system culturing facilities. Diverse species from different genera and families which mainly reproduce sexually should be involved to obtain knowledge about specific settlement preferences and recruitment properties. To provide statistical evidence, large numbers of propagules and several independent testing-systems are required. Propagules need to be cultured for several months or years to achieve colonies of a size class which might provide good survival in nature.

One of the most challenging problems in operating closed- and open-systems in a long-term project is financial support. The need for outside funding and operating costs could be reduced by collaboration with semi-scientific and commercial facilities such as public aquaria and coral farms. Several public aquaria have been successfully culturing and reproducing (mainly asexually) scleractinian corals for the past several years (Carlson, 1987; Atkinson et al., 1995; Adey and Loveland, 1998; Borneman, 1999). Juvenile colonies do not require much space but high water quality which can be provided by those institutions. As a rule cultivation facilities in public aquaria already exist in non-exhibiting areas which could probably be used for most of the studies. Public aquaria are an important tool for education. Exhibiting such a research program to the public will help increase awareness of the critical situation of coral reefs. Commercial mariculture-facilities (coral farms; see Tullock, 1997; Adey and Loveland, 1998) can provide job opportunities for coastal populations, especially for fishermen who often practice excessive and destructive fishing methods which cause great damage to coral reefs (Roberts, 1995; McManus, 1997). In this way a new basis of subsistence can be given to local people, anthropogenic reef destruction will be further on reduced, and local people would help to protect their reefs. To obtain self-sufficiency, some of the cultured corals could be sold to the aquarium trade or to the pharmaceutical industry, which would reduce collection from the reefs.

Special regard should be given to the genetic quality of parental colonies. Genotypes should be chosen in a way to preserve genetic diversity and to minimize inbreeding, genetic drift and founder-effects. If genetic diversity is drastically reduced, variation and subsequently the potential to adapt to changing environmental conditions will be lost.

Corals are clonal organisms that have developed complex life-histories involving various reproductive modes (Fadlallah, 1983; Harrison and Wallace, 1990), which might result in self-fertilization (Stoddart, 1988) or hybridization (Szmant et al., 1997; Willis et al., 1997; Hatta pers. comm.). Other life-history parameters such as indeterminate growth and the potential loss of senescence also need to be considered (Hughes et al., 1992; Hall and Hughes, 1996). Investigations using molecular techniques to understand the role of sexual reproduction indicate great intra- and interspecific differences in its importance among scleractinian corals (Hunter, 1993; Stoddart, 1984; Ayre and Dufty, 1994; Benzie et al., 1995). Genetic diversity among populations of *Porites compressa* Dana 1846 increased with moderately high disturbance rates while low disturbance caused low levels of genetic diversity (Hunter, 1993). The cited studies applied allozyme-electrophoresis to identify genotypes. More recently attempts have been made to develop methods with higher resolution such as coral-specific DNA markers (Takabayashi et al., 1998a,b), DNA fingerprints (Coffroth, 1997) or microsatellites (Rinkevich, pers. comm.). These techniques will probably help to estimate genetic diversity among natural populations and potential parental colonies for ex situ fertilization.

Another important point for preserving genetic diversity in in situ and ex situ populations might be the latent danger of coral-specific pathogens. In general there exists probably not only a species-specific relationship between parasite and host, but even more a genotype-specific correspondence resulting in a gene-for-gene relationship between virulence and resistance (Begon et al., 1996). Out of all supposed coral diseases, only three have been identified and two pathogens isolated. Several new diseases have been incompletely characterized (Richardson, 1998). In situ populations like the corals on reefs in the Florida keys suffer from outbreaks of numerous, potential new pathogens probably enhanced by anthropogenic impact of coastal populations (current articles in newspapers, see also Patterson et al., 1997), such effects have also been observed in ex situ populations of scleractinian corals maintained in private aquaria which have been attacked by parasites often resulting in total loss of individuals of one or more species.

To restore damaged reefs and to preserve genetic diversity, molecular studies of populations will be necessary to decide whether asexual recruits by transplantation (Guzman, 1993; Yates and Carlson, 1993; Clark and Edwards, 1995; Oren and Benayahu, 1997) or sexual recruits are preferable. Rinkevich (1995) proposed to manage damaged reefs by the use of asexual and sexual recruits and emphasized that the applicability of sexual recruits for restoration management had not been tested. In our opinion it is important to recognize the value of both strategies to provide effective reef management.

The global mass coral bleaching in 1998 showed dramatically how sensitive scleractinian corals are to environmental changes. Continuously increasing anthropogenic stress on coral reefs will result in reduced fecundity and survival of propagules. The establishment of methods to preserve sexual recruitment in coral reefs is now more important than ever to maintain genetic diversity.

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