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Chapter 32

Introduction: *Ex-situ* coral population management: towards sustainability and breeding programs

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INTRODUCTION

Coral husbandry mainly concerns key species of a threatened ecosystem – the coral reef. Public aquaria have a great responsibility when displaying corals. Apart from raising public awareness in their traditional role, aquaria increasingly focus on sustainable practices to manage their life stock.

Fragmentation as a method to propagate coral asexually is meanwhile widely applied in the aquarium field. Parts of a colony are removed and transplanted on a new substrate. The clones that are genetically identical to the donor colony usually quickly attach to the substrate and form a new colony. Meanwhile, thousands of ramets of mainly branching species have been distributed among public aquaria worldwide (Brittsan, Carlson, Carl and Falcato, pers. com.). Additionally, the culture of coral fragments in *ex-situ* and *in-situ* nurseries may be an important source to provide life stock in a sustainable way. However, sexual reproduction has been a myth in public aquaria for a long time. Although the sudden appearance of new specimens, which may be a sign for sexual reproduction, had been occasionally observed in a few aquaria in the past, no techniques were available to use this mode for the production of sexual recruits. Nevertheless, intensive research carried out by scientists and public aquaria has enabled an increasing number of public aquaria to use sexual reproduction as a source to gain high numbers of sexual recruits (Fan *et al*., 2004; Nonaka *et al*., 2003; Petersen *et al*., 2006; 2007). The spectrum of captive bred species is steadily increasing which might indicate good perspectives for sustainability and breeding programs.

Due to the complexity of reproductive modes in corals which may lead to significant intraspecific variation between local populations, long-term management of *ex-situ* populations in public aquaria is challenging, especially if reintroduction should be envisaged in future. Scientists have made great efforts to get a better understanding of genetics in corals with reasonable success; nevertheless, more cooperation is needed between public aquaria and scientists in order to draft a management plan for captive populations. Innovative cryopreservation techniques may provide an important tool to preserve genetic diversity in *ex-situ* and *in-situ* populations, and to establish gene banks for endangered species. In modular organisms with a complex reproductive biology, record keeping and tracking of individual genotypes is essential to manage captive populations and to coordinate breeding efforts. Whilst molecular tools can help identify likely origins of captive animals and to find out whether they were sexually or asexually produced, global databases such as ZIMS (Zoological Information Management System) may provide an overview among groups of clones or individuals in public aquaria which may serve as a basis for studbooks (see www1).

Regarding the devastating situation of today's coral reefs, captive population management of corals in public aquaria should be connected to *in-situ* population management. Captive populations could be managed in a way to potentially provide coral material for the preservation of endangered field populations

SUSTAINABILITY AND BREEDING PROGRAMS

In times of constant reef decline, coral population management in public aquaria is inevitably connected to coral conservation. As a consequence, main goals of modern coral population management should address sustainability and coordinated breeding programs for threatened or endangered species.

The management of captive coral populations may include effective asexual and sexual propagation techniques to breed corals, adequate record keeping to overview populations within an institution and between institutions, and molecular techniques to oversee coral genetics. Last but not least, innovative research areas such as coral cryopreservation may serve in future as an important source for supplying aquaria with breeding material.

ASEXUAL REPRODUCTION

Most corals develop colonies from extra- or intrapolypal fission (Schuhmacher, 1976). Asexual ramets may be produced through budding (Zibrowius, 1985), polyp bail-out (Sammarco, 1982), polyp balls (Rosen and Taylor, 1969), anthocauli (Krupp *et al*., 1993), asexual planulae (Stoddart, 1983) and fragmentation including the skeleton (Highsmith, 1982). The result of all types of asexual reproduction are genetically identical coral polyps, called ramets. Among all known modes of asexual reproduction, fragmentation is the most important one for propagating corals in captivity. Pieces of mainly branching species can be broken off the donor colony and reattached to adequate substrate using epoxy cement, zip ties, rubber bands, nylon, etc. Fragments usually develop within a few days to weeks into new colonies. Details on techniques applied in the aquarium field can be found under Calfo (2001), Delbeek and Sprung (1994) and Fossa and Nilsen (2002). Fragmentation techniques have been developed in coral mariculture to supply aquaria (Rinkevich and Shafir, 2000) and to restore damaged reefs (Epstein *et al*, 2001; Van Treek and Schuhmacher, 1997). Especially in branching species, fragmentation may represent an important natural mode of reproduction in coral reefs (Harrison and Wallace, 1990; Highsmith, 1982; Wallace, 1985).

Regarding population management, fragmentation can be an effective tool to quickly produce medium sized coral propagules. Depending on the initial fragment size, high post-transplantation survival rates of nearly 100 % can be routinely achieved. In this way, thousands of transplants may be relatively easily produced and exchanged between public aquaria. However, fragmentation does not contribute to the maintenance of genetic diversity in captive populations. Whilst small polyped species can be relatively easily fragmented using a cutter or an electrical saw, larger polyped species such as *Trachyphyllia* sp. may be almost impossible to reproduce asexually by fragmentation (Carlson, pers. com.; D. Petersen, pers. observation).

SEXUAL REPRODUCTION

Corals have evolved various modes of sexual reproduction, which can be divided into broadcast spawners and brooders with most corals being hermaphroditic (for details in modes of reproduction, see Harrison and Wallace, 1990). Since a few years, the application of sexual reproduction in the aquarium field has steadily increased, due to intensive research and optimized husbandry conditions.

Aquarists and scientists agree that in the near future sexual reproduction will serve as an important tool to sustain captive coral populations (Delbeek, 2001; Petersen *et al*., 2007). In principle, hundreds of thousands of propagules can be easily obtained from sampling only a few donor colonies. By nature, sexual reproduction helps sustaining genetic diversity. Another advantage is the low amount of labor to produce high numbers of sexual recruits compared to fragmentation where each specimen has to be handled individually at least at the time of transplanting it. However, compared to the spectrum of species displayed in public aquaria, only relatively few species can be currently reproduced sexually in captivity. Even less species have been reported to fulfill a full life cycle under captive conditions. Theoretically, all displayed coral species could be reproduced sexually in the aquarium environment. However, the control of sexual reproduction of specific species needs further research and specific attention of the aquarist.

SEXUAL VS. ASEXUAL REPRODUCTION

Ideally, in any breeding effort asexual and sexual reproduction should be combined in a way to get as close as to the natural life history of a specific coral species. Whether a coral tends to reproduce sexually or asexually, may highly depend on species specific properties and on the environment (Harrison and Wallace, 1990; Wallace, 1985). Regarding coral conservation, especially genetic aspects will determine which reproductive mode has to be chosen for a specific species (see also below and Baums, 2008). Regarding coral husbandry and propagation, practical aspects will determine whether to use asexual or sexual methods. A combination of asexual and sexual methods might be a useful attempt to maximize the propagation success. In comparison with other animal groups which are captive bred in zoos and public aquaria, corals are extremely challenging due to their great variety of reproductive modes and plasticity in their life history strategies. Before any breeding program or reintroduction efforts are initiated, experts such as population geneticists have to be consulted to estimate mid- to long-term effects. Besides the reintroduction guidelines set up by the Re-introduction Specialist Group of the IUCN (IUCN, 1998), various ecological and genetic aspects have to be specifically considered due to the complexity of the coral reef ecosystem and population genetics in corals. Public aquaria, scientists and authorities are currently working on a reintroduction protocol for the threatened Staghorn coral *Acropora cervicornis* in Florida, USA (Brittsan and Czaja, pers. com.). Besides conservation related aspects, other factors such as specific pathogens which may spread rapidly in clonal populations (see chapter 5) should be considered in mid- to long-term *ex-situ* population management.

RECORD KEEPING

Record keeping is difficult in modular organisms, especially if they show a high degree of phenotypic plasticity. If the field collection site is not well documented (custom's confiscations, trade), the exact place of origin will never be known; however, this is essential for any serious breeding attempt. Additionally, when corals are exchanged between aquarium systems within an institution or in between institutions, specimens often change their growth and color within weeks in response to different aquarium conditions which makes it difficult to follow their track unless molecular genetic tools are applied. Public aquaria usually maintain higher numbers of specimens per species which may be fragmented or transferred between different systems. Compatible specimens of one species which may have different origins might produce offspring in an aquarium system; it will be probably difficult to determine which parents have contributed with their genome to this offspring since e.g. gametes are transmitted through the water column.

It is clear that adequate record keeping as part of coral population management is currently limited or even impossible. The International Species Information System (ISIS; www2) is developing new software to improve record keeping in zoological gardens and aquaria. The Zoological Information Management System (ZIMS) will be an extremely useful tool to overview captive populations of organisms with a complex reproductive biology such as corals.

MOLECULAR GENETICS

The understanding of genetics in corals and the identification of species, populations and individuals on a molecular basis plays a key role in captive population management. Population genetics in corals have been increasingly studied by scientists; more techniques such as microsatellites in order to distinguish individual genotypes within a populations are nowadays available. For public aquaria, it will be essential to collaborate with experts in this field in order to successfully establish captive breeding programs. A recent study on *Acropora palmata* showed high variation of genetic diversity between field populations of different locations in the Caribbean (Baums *et al*., 2005). Genetic analyses gave evidence that there are two distinct regions within the Caribbean with genetically isolated *A. palmata* populations. These are in the Eastern and Western Caribbean with Puerto Rico defined as a mixed, 'transition' region (Baums *et al*., 2005). In most areas along the southern Florida coast, population structure for this species has collapsed. All of the *A. palmata* in these areas consist of a clone produced from fragmentation and growth of a single individual (Baums *et al*., 2005). However, there is at least one remaining area of the Western Caribbean that still has high genetic variation (Baums *et al*., 2005). Therefore, genetic material (eggs/ sperm) for breeding purposes should be first carefully examined on a molecular basis to ensure sufficient genetic diversity before any breeding attempt is initiated.

CRYOPRESERVATION

"Cryopreservation is a process where cells or whole tissues are preserved by cooling to low sub-zero temperatures, such as −196 °C (the boiling point of liquid nitrogen). At these low temperatures, any biological activity, including the biochemical reactions that would lead to cell death, is effectively stopped. However, when vitrification solutions are not used, the cells being preserved are often damaged due to freezing during the approach to low temperatures or warming to room temperature…" (www3). Recently, Mary Hagedorn (Smithsonian National Zoological Park, USA), a leading aquatic cryobiology scientist has started to establish techniques for successfully cryopreserving coral gametes and larvae. Hagedorn *et al*. (2006a, 2006b) successfully cryopreserved spawn of the mushroom coral *Fungia furcata*, initial studies on the threatened species *Acropora palmata* (see Chapter 42) indicate that this method in conjunction with gene banks will not only be an important tool for preserving endangered coral species from extinction, but also serve as an important tool for coral breeding activities in public aquaria.

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INTERNET RESOURCES

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www2. www.isis.org

www3. http://en.wikipedia.org/wiki/Cryopreservation