

## Testing the first phase of the ‘gardening concept’ as an applicable tool in restoring denuded reefs in Tanzania

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### ABSTRACT

Studies on coral reef restoration through a two-step coral gardening protocol have lately proved it to be a viable solution for future reef restoration. This involves a first step of gardening small colonies in mid-water nurseries and a second step, their transplantation, upon reaching suitable size, onto the pre-surveyed damaged areas. We established in September 2007 two mid-water nurseries, each holding 10,000 fragments measuring 2 cm average initial size, at 4 m depths (high tide) in Zanzibar and Mafia Islands, Tanzania. Each nursery comprised six species, each of which was represented by three genotypes. During 9 months, we followed developments by analyzing and comparing survivorship and growth rates of fragments between the different nurseries, species and genotypes. A significant difference between species survival and growth rates was observed in acroporid species, in *Pocillopora verrucosa* and *Millepora* sp., which showed better success than *Porites cylindrica*. In both sites, *Millepora* suffered no mortality and other species exhibited low mortality, ranging (per coral genotype) between 3% and 24% in Zanzibar (most cases below 10%) and between 13% and 44% (mostly below 25%) in Mafia Island. Most of fragments' mortality occurred during the first two nursery months. Coral species in Zanzibar nursery also performed better in growth rates than those in Mafia, but in both sites, farmed corals were ready for transplantation just 9 months after the nursery was set up. Economic evaluations involved in the overall nursery set-up and the results indicated that the coral gardening approach could be used in Tanzania to generate large quantities of coral colonies for the restoration of damaged reefs at relatively low cost.

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### 1. Introduction

The culprits responsible for the unprecedented worldwide coral reef decline are primarily anthropogenic in nature (Hughes et al., 2003; Bell et al., 2006), and their impacts are intensified by major natural disturbances such as storms (Connell, 1997; Crabbe et al., 2008; Garrison and Ward, 2008), crown-of-thorn outbreaks (Kenneth, 1994; Nicholas et al., 2004) and massive coral bleaching events (Williams et al., 2001; Hoegh-Guldeberg et al., 2007). Tanzanian fringing and patch reefs, stretching along about 800 km of continental shelf, have been, with no exception, most severely hit by anthropogenic activities and natural catastrophes, with significant proportion of the reef structures damaged beyond the

power for natural repair (Lindahl, 2003). In Tanzania, the reef system comprises a very significant natural resource on which coastal fishing communities depend entirely for their livelihood (Darwall and Guard, 2000; Muhando et al., 2002; Mbije, 2001; Mbije et al., 2002). In fact, 70% of artisanal fisheries of Tanzania come from the coral reef ecosystems (Jiddawi and Öhman, 2002), which supply 90% of the animal protein consumed and the primary source of income for the people (Wagner, 2004). Tanzanian coral reefs are also a major tourist attraction. Coastal tourism based on coral reefs brings foreign currency into the country and provides livelihoods for coastal people through employment and other services. With these products and services provided by Tanzanian reefs, any sign of habitat destruction, even before documenting major biodiversity devastation and extensive species losses, would be sufficient cause for alarm, to promote immediate and imperative mitigation measures. This tenet is further backed by the continuous regression of Tanzanian reefs, a decade following massive bleaching events (Mohammed et al., 2000; N. Mbije, pers. obs.), which, while instigating active conservation schemes and several rehabilitation

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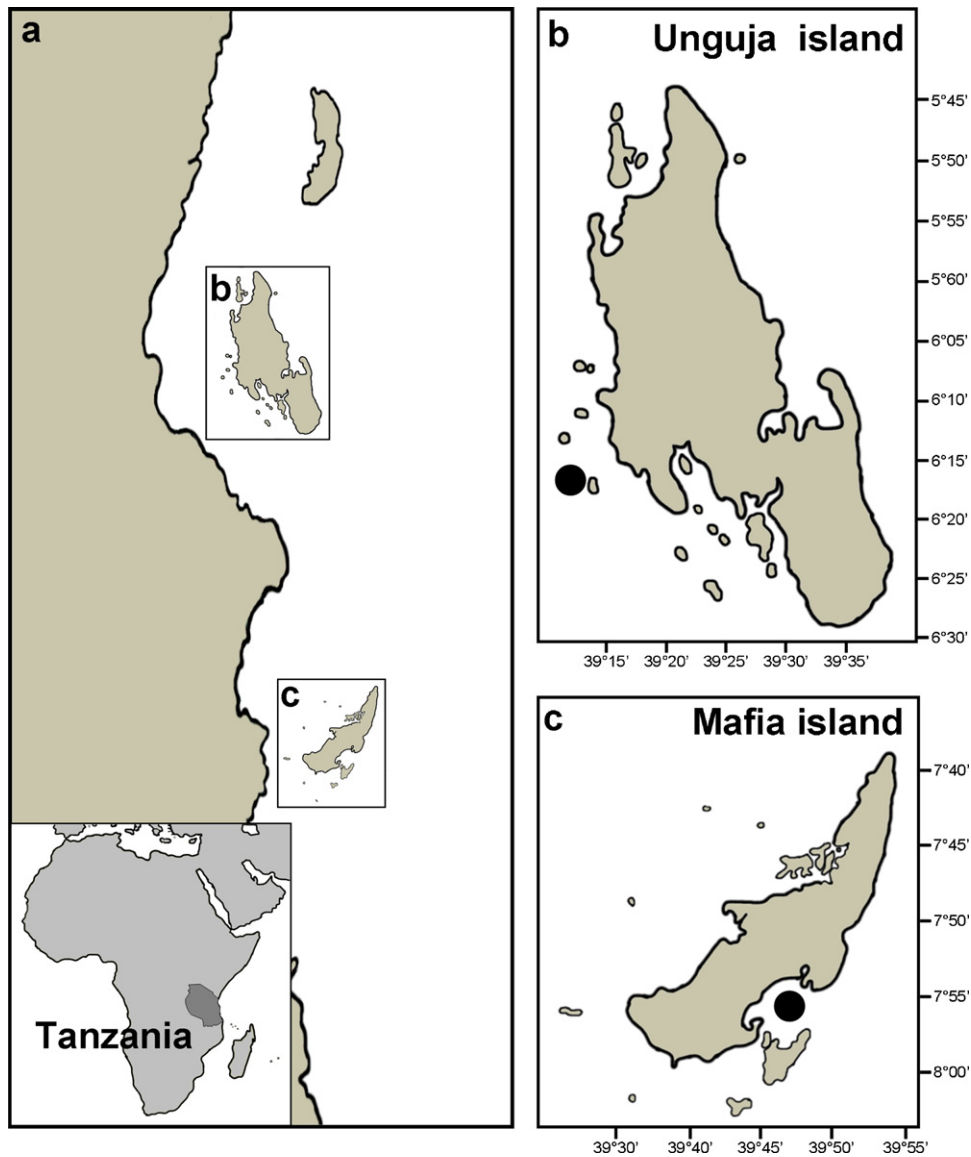


Fig. 1. Map of the coast of Tanzania (a) and Tanzania (Africa insert), showing Chumbe nursery site in Zanzibar (b) and Chole Bay site in Mafia Island (c).

programs, have yielded no obvious success (Franklin et al., 1998; Lindahl, 1998, 2003). This failure to promote a working hypothesis for Tanzanian reef restoration resembled worldwide attempts that resulted in unsatisfactory, sometimes conflicting, outcomes (Harriott and Fisk, 1988; Gleason and Wellington, 1993; Bowden-Kerby, 1997; Edwards and Clark, 1998; Bruckner and Bruckner, 2001; Rinkevich, 2005a,b, 2006, 2008). Additionally, many of these attempts employed techniques that were either labor intensive or too expensive to be applied in a developing country like Tanzania.

To overcome these obstacles, a two-step restoration operation termed the 'gardening concept' (Rinkevich, 1995, 2000, 2005a, 2006, 2008; Epstein et al., 2001; Epstein and Rinkevich, 2001) was introduced and weighed against traditional conservation acts. This concept incorporates stock farming of small coral fragments in mid-water nurseries (step 'a') which, upon reaching suitable sizes, are transplanted onto denuded reef areas (step 'b'). This notion for active reef restoration had been tested and proved to be successful in studies employed in the northern Gulf of Eilat, Red Sea (Rinkevich, 2006, 2008; Shafir et al., 2006a,b) and

recently in other localities worldwide, including the USA (Herlan and Lirman, 2008), the Philippines (Shaish et al., 2008) and Thailand (Putchim et al., 2008). Furthermore, the gardening technique has been found to be the least laborious, the least costly and with a high yield of survivor and growth rates (Rinkevich, 2006; Shafir et al., 2006a,b; Amar and Rinkevich, 2007; Shafir and Rinkevich, 2008; Shaish et al., 2008, 2010; Levy et al., 2010). Different localities worldwide represent site-specific conditions and unlike working considerations (Shafir et al., 2006a; Shaish et al., 2008, 2010; Levy et al., 2010). This calls for general standardization of the basic protocols, particularly the development of effective and approved-to-use regional-specific protocols that would transfer restoration activities into a unified conceptual and practical scheme.

The present study, the first gardening project initiated in East Africa, aims at testing the applicability and efficiency of the concept for restoring reefs in Tanzania damaged by human activities and the deadly 1997/1998 SST warming event. We concentrated on step 'a' of the gardening concept, farming coral colonies in underwater floating nurseries.

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