Tanzanian Reef Building Corals May Succumb to Bleaching Events: Evidences from Coral-*Symbiodinium* Symbioses

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Abstract

Coral reefs are among the most vulnerable ecosystems to current trends of climate change. Most of the reef systems along the coast of Tanzania have remained severely damaged following the 1997/1998 El-Niño that caused a massive coral bleaching, resulting into a wide spread of coral death. It is important therefore to find out/establish whether reef building corals develop adaptations to current trends of climate change so as to prioritise their conservation. There are evidences that coral-*Symbiodinium*-symbioses develop adaptation to current trends of climate change. This review therefore was meant to compare coral-*Symbiodinium* symbioses that occur along the Tanzanian coast with those occurring in others parts of the world. Like in most parts of the world, reef building corals along the Tanzanian coast are dominated by *Symbiodinium* clade C3 which is both thermal and irradiance intolerant. In the Tanzanian coast, coral genera that in most part of the world have been found to host clade D, the *Symbiodinium* type whose distribution is correlated with warmer environment, host other *Symbiodinium* clades. Unlike in most part of the world, most of Tanzania's reef building corals lack polymorphic symbioses, a phenomenon that is hypothetically believed to render environmental tolerance to the holobiont. This is probably due to low seasonal variation in both temperature and solar radiations. Thus, Tanzanian corals become less advantaged in terms of impacts that may be associated with current trends of climate change.

Keywords

Tanzanian coast • Reef building coral • Estuarine • Coral bleaching • *Symbiodinium* types • Climate change

Introduction

Coral reefs, often referred to as 'the rain forests of the ocean' due to their high biodiversity (Reaka-Kudla 1995), play a key role in the functioning of tropical coastal ecosystems through their ability to shelter a huge diversity of sessile and free-living organisms. Although coral reefs cover only less than 0.5% of the world's sea floor (Spalding and Grenfell 1997), they provide critically important goods and services to over 500 million people worldwide, mainly through fisheries and tourism industries (Moberg and Folke 1999).

Regarding fishery, coral reefs provide suitable reproductive spawning habitats and nursery ground to most fish species found in mangroves and seagrass beds (Lugendo et al. 2005; Mumbi 2006; Kimirei et al. 2011). There is scientific consensus showing mangroves, estuarine (zone between rivers) and sea grass ecosystems to significantly contribute to coral reefs fish populations (Verweij et al. 2008; Kimirei et al. 2013). This is possible through the ability of mangroves and seagrass to provide shelter against predators, nursery and feeding grounds to juveniles

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of many coral reef fishes (Lugendo et al. 2006, 2007; Verweij et al. 2008; Kimirei et al. 2013). For example, studies which were conducted in the Caribbean show about 17 of reef fish species to associate with estuaries and mangrove ecosystems (Nagelkerken et al. 2002; Dorenbosch et al. 2005; Mateo et al. 2010; Kimirei et al. 2011). In fact, in islands where there are no estuaries and or mangroves, those species were not found in adjacent reefs. Likewise, recent studies which were conducted in the Western Indian Ocean (WIO) region show mangroves and seagrass beds to replenish coral reef fish populations where sub-adult and adult fishes from mangroves and seagrass beds migrate to coral reefs for spawning (Kimirei et al. 2013). In Tanzania, mangroves occur on the sheltered shores of deltas, alongside river estuaries, and in creeks where fine-grained sediment (silt and clay) is abundant in the upper part of the inter-tidal zone (Wang et al. 2003). Along the Tanzania shoreline, well established mangroves with high fishery potential are found in extensive estuaries of Ruvuma, Fufiji and Ruvu estuaries. As indicated above, all these estuaries together with others which are smaller contribute significantly in improving coral reef fisheries in Tanzania which give employment to a good number of coastal dwellers.

The mangroves also help to reduce the amount of sediments going into other coastal ecosystems such as seagrass and coral reefs. Since the two ecosystems are intricately dependent, destruction of one would mean ecological disturbance of the other.

Furthermore, coral reefs provide coastal protection and stabilization by reducing wave energy and mitigating both routine erosion and damage from waves associated with small and moderate storm events. Current trends of climate change are accompanied by global warming, sea level rise and increased storm intensity (Hoegh-Guldberg 1999; Wilkinson 2002). Therefore, coastal protection will increasingly become more important. Coral reef ecosystems also may represent a biological source for new drugs and biochemicals that need to be explored. However, coral reefs are known to be fragile because they support a large number of delicate invertebrates that are susceptible to human-induced disturbances (Reaka-Kudla 1995). Thus, continued provision of these goods and services is threatened by recent increase in physical, chemical and biological stresses on corals (Hughes, 1994). It is estimated that such stresses would cause a decline of 40% to 60% of the world's coral reefs over the next 50 years if appropriate and corrective measures are not taken (Hoegh-Guldberg 1999; Wilkinson 2002; Hughes et al. 2003).

The survival of coral reefs ecosystem worldwide is threatened by coral bleaching which is a manifestation of current trends of climate change accompanied by global warming. Coral bleaching is a general term referring to the disappearance of the coloured pigments because of either degradation of algal pigments and/or partial to total loss of their *Symbiodinium* population to the extent of revealing the white coral skeleton (Glynn 1993; Hoegh-Guldberg 1999, Douglas 2003). Like other Cnidarians, scleractinian corals host photosynthetic dinoflagellates belonging to the genus *Symbiodinium*, commonly called zooxanthellae, within the vacuoles of their gastrodemal cells. These dinoflagellates are known to largely contribute to corals' metabolic demand in nutrient poor (oligotrophic) tropical environments (Muscatine 1990). About 40% of photosynthetic products in the *Symbiodinium* cell are translocated to coral tissues to meet up to over 90% of the coral's energetic demands (Johnson 2011). Due to high coral energetic reliance on photosynthetic products from *Symbiodinium*, bleaching impairs reproduction, growth rates, and general immunity of the corals (Hoegh-Guldberg 1999; Baird and Marshall 2002; Hughes et al 2003). In a situation where factors that cause bleaching are severe and persist for a long time, coral mortality occurs (Brown 1997; Douglas 2003).

Major factors that cause coral bleaching include sea surface temperature rise (Saxby et al. 2003, Barron et al. 2010) and/or drop (Hoegh-Guldberg and Fine. 2005), and UV radiation (Brown et al. 1994; Brown 1997; Dunne and Brown 2001; Winters et al. 2003). In fact, major coral bleaching events that pose the greatest management challenges to coral reef ecosystems worldwide are correlated with *El Nino and* Southern Oscillation (ENSO) events which are accompanied by both higher SST and solar radiation (Fitt and Warner 1995; Hoegh-Guldberg 1999; Lough 2000; Hueerkamp et al. 2001). Moreover, factors such as bacterial infection (Rosenberg and Falkovitz 2004), lowered salinity, and pollution (Glynn 1993) have also been documented to cause small scale bleaching events.

During the 1997/1998 worldwide coral bleaching event up to 90% reduction in coral cover in some places along the Tanzanian coast was recorded (Muhando 1999, Wilkinson et al. 1999; Lindahl et al. 2001). For example, Misali and Tutia reefs in Pemba and Mafia Islands respectively were the most affected when compared with other reefs. About 90% of these reefs suffered coral mortality following the 1997/1998 bleaching event. Other reefs such as Chumbe and Kwale in Zanzibar and Mikindani in Mtwara experienced coral mortality that ranged from 30% to 50%. Corals at Bawe, Changuu and Chapwani in Zanzibar, and Pangavin and Mbudya in Dar es Salaam were the least affected (mortality ranged from 11% to 20%). By 2007, most reefs have not recovered except very few (Muthiga et al. 2008).

Coral-*Symbiodinium* Symbioses in Relation to Bleaching Resistances

Differences in bleaching susceptibilities among coral species are well documented (Wilkinson et al. 1999; Marshall and Baird 2000; Lindahl et al. 2001; Hueerkamp et al. 2001;

Garpe and Öhman 2003; Sampayo et al. 2007). Such differences can be in terms of geographical area (Goreau and Hayes 1995; Hueerkamp et al. 2001), time (Berkelmans and Willis 1999), species, and individual colony history (Marshall and Baird 2000; Sampayo et al. 2007). Studies show *Acropora* and *Pocillopora* to be among the most susceptible genera (Hoeg-Guldberg and Salvat 1995; Marshall and Baird 2000; Lindahl et al. 2001). The Tanzanian coast is dominated by *Acropora* and *Porites* (Obura et al. 2004) which are susceptible and tolerant to bleaching, respectively. Although susceptibility of holobiont (coral and symbiont) to bleaching depends on both partners in symbioses, this review focuses on *Symbiodinium* (symbiont) as one of important inducer of tolerance to bleaching.

Although the host contribute significantly to bleaching susceptibility of the holobiont (Baird et al. 2009; Fitt et al. 2009), different *Symbiodinium* species hosted by the corals largely explain the observed difference in bleaching susceptibility among coral species (Warner et al. 1996; 2006; Bhagooli and Hidaka 2003; Iglesias-Prieto et al. 2004). This is due to the fact that, different species of *Symbiodinium* differ in terms of their thermal and irradiance tolerances (Kinzie et al. 2001; Bhagooli and Hidaka 2003). Such differences in thermal tolerance among *Symbiodinium* species is attributed to differences in photochemical responses (Winters et al. 2003; Bhagooli and Hidaka 2003; Iglesias-Prieto et al. 2004; Warner et al. 2006; Frade et al. 2008). *Symbiodinium* clade D is believed to be relatively more thermally tolerant due to its presence in marine habitats with chronically high temperatures (Fabricius et al. 2004; Glynn et al. 2001) and environmental disturbances (Toller et al. 2001; Berkelmans and van Oppen 2006; Rowan 2004; Baker et al. 2004; Stat and Gates 2011). A study that monitored seasonal variation in *Symbiodinium* types found an increase in the frequencies of clade D during hotter seasons (Chen et al. 2005). Basing on the fact that major bleaching events are correlated with rise in sea surface temperature, clade D is considered to be among the *Symbiodinium* types that can help corals to survive the current trends of climate change.

Distribution of *Symbiodinium* Clade D in Tanzanian Corals

Coral may acquire *Symbiodinium* cells including those belonging to clade D either vertically or horizontally. In vertical (also known as maternal) transmission strategy, *Symbiodinium* cells are present in the eggs or brooded planulae larvae prior to release from the parent (Trench 1987). However, in horizontal transmission strategy, released eggs and larvae do not have *Symbiodinium* cells. These juvenile corals acquire *Symbiodinium* cells from the ambient environment (Trench 1987). Most corals in most reefs around the world have been found to have potential of hosting *Symbiodinium* clade D (Oliver and Palumbi 2010; Ghavam Mostafavi et al. 2007). One should be cautious though, when reviewing diversity and distribution of *Symbiodinium* in reef building corals. This is due the employment of molecular approaches that have been found to over-estimate diversity of *Symbiodinium* in the coral host (Thornhill et al. 2007; Sampayo et al. 2009). These include those involving the cloning of PCR products and the use of real time PCR in the estimation of *Symbiodinium* diversity. To avoid such over estimation, only previous studies whose approaches in analysis of *Symbiodinium* types do not lead to overestimation of diversity of *Symbiodinium* types in the coral tissue were included in Tables 1 and 2. Therefore, only the study that involved Restriction Fragment Length Polymorphism (RFPL), Single Strand Conformational Polymorphism (SSCP) and Denaturing Gradient Gel Electrophoresis (DGGE) were included in Tables 1 and 2. These approaches have ability to detect *Symbiodinium* types in the coral tissue that are actually responsible for the physiology of the holobiont.

As presented in Table 1, a range of coral genera from fast growing branching (*Acropora*, *Stylophora*, *Seriatopora* and *Pocillopora*) to slow-growing massive corals (*Montastrea*), encrusting (*Montipora*) and solitary (e.g., *Fungia*) corals have been found to host *Symbiodinium* clade D globally (Table 1). In fact, in the Persian Gulf and Iran where sea surface temperatures are extremely high with very high seasonal fluctuations, *Porites* was found to establish symbiosis with *Symbiodinium* clade D (Mostafavi et al 2007). In other parts of the world, *Porites* has maintained symbiosis with *Symbiodinium* C15 type, probably because the symbiont has been found to be both thermo and irradiance tolerant (Fitt et al. 2009). However, in Tanzania only *Seriatopora*, *Galaxea* and *Acropora* in a few reefs have been found to host *Symbiodinium* clade D (LaJeunesse et al. 2010; Chauka 2012). Unlike in other regions where a large number of coral genera have been found to host *Symbiodinium* clade D, Tanzanian reef building corals are dominated by C3u and C3z (Chauka 2012), which are both thermal and irradiance intolerant (Chauka et al. in press).

Clade D *Symbiodinium* is present in higher abundance on some reefs than on others. In most cases, such difference is attributed to differences in exposure to sea surface temperature. For example, Oliver and Palumbi (2009) found higher abundance of *Symbiodinium* clade D in *Acropora* samples collected from back-reef lagoons in American Samoa. The sea surface temperature in these reefs was found to be higher when compared with other places in American Samoa. Other factors that can cause differences in distribution of *Symbiodinium* clade D in a particular region include turbidity and history of coral bleaching. In Tanzania, high turbidity seems to play a significant role in the distribution and abundance of

Table 1 Examples of coral genera which have been found to host Symbiodinium clade D in different part of the world and compared with the same genera in Tanzanian coast

Coral genera hosting Clade D Symbiodinium	Place observed with reference	Presence/Absence in Tanzania
Pocillopora	Carribean (Iglesias-Prieto et al. 2004), North Indian Ocean (LaJeunesse et al. 2010); Great Barrier Reef (Stat et al. 2009)	No (LaJeunesse et al. 2010; Chauka 2012)
Astreopora	North Indian Ocean (LaJeunesse et al. 2010)	No (LaJeunesse et al. 2010; Chauka 2012)
Montipora	Hawaii (LaJeunesse et al. 2004a, b, c), North Indian Ocean (LaJeunesse et al. 2010)	No (LaJeunesse et al. 2010; Chauka 2012)
Echinopora	North Indian Ocean (LaJeunesse et al. 2010)	No (LaJeunesse et al. 2010; Chauka 2012)
Favia	North Indian Ocean (LaJeunesse et al. 2010); Persian Gulf, Iran (Mostafavi et al. 2007)	No (LaJeunesse et al. 2010; Chauka 2012)
Goniopora	North Indian Ocean (LaJeunesse et al. 2010)	No (LaJeunesse et al. 2010; Chauka 2012)
Pavona	North Indian Ocean (LaJeunesse et al. 2010); Persian Gulf, Iran (Mostafavi et al. 2007)	No (LaJeunesse et al. 2010; Chauka 2012)
Seriatopora	North Indian Ocean (LaJeunesse et al. 2010)	Yes (LaJeunesse et al. 2010; Chauka 2012)
Galaxea	Kenya (Visram and Douglas, 2006), North Indian Ocean (LaJeunesse et al. 2010), Curaçao (LaJeunesse et al. 2004a, b, c)	Rare (LaJeunesse et al. 2010; Chauka 2012)
Goniastrea	North Indian Ocean (LaJeunesse et al. 2010); Great Barrier reef (Stat et al. 2009), Caribbean (LaJeunesse et al. 2004a, b, c)	No (LaJeunesse et al. 2010; Chauka 2012)
Montastrea	Belize, Caribbean (Toller et al. 2001; Garren et al. 2006), North Indian Ocean (LaJeunesse et al. 2010)	No (LaJeunesse et al. 2010; Chauka 2012)
Favites	Penghu Islands (the Pescadores) Taiwan and from Hong Kong (Chen et al. 2005)	No (LaJeunesse et al. 2010; Chauka 2012)
Platygyra	North Indian Ocean (LaJeunesse et al. 2010); Persian Gulf, Iran (Mostafavi et al. 2007)	No (LaJeunesse et al. 2010; Chauka 2012)
Porites	Persian Gulf, Iran (Mostafavi et al. 2007)	No (LaJeunesse et al. 2010; Chauka 2012)
	Palauan reefs	

Symbiodinium clade D. Most reefs in Zanzibar are exposed to similar sea surface temperature (Chauka 2012). However, clade D was found in higher abundance in Chapwani and Changuu reefs, the most turbid reefs, while in Bawe and Munemba Clade D was absent (LaJeunesse et al. 2010; Chauka 2012). Likewise, clade D was sampled in Mbudya (39014′52.45″E, 6039′33.76″S), Dar es Salaam; a place where turbidity was found to be high. In a very close reef; Pangavin (39°14′17.77″E, 6°40′27.37″S) where turbidity is low, clade D was not sampled. In fact, low mortality in Mbudya reef, Dar es Salaam following the1998 bleaching event is attributed to high turbidity that might have prevented higher solar radiations reaching the surface of the coral and not the presence of *Symbiodinium* clade D (Chaukaet al. in press). This is due to the fact that corals species that were not found to host *Symbiodinium* clade D which are known to be bleaching susceptible such as *Seriatopora*, were not severely affected in Mbudya, Dar es Salaam as compared in other reefs (Muhando 1999).

With regard to bleaching history, several studies have shown increases in the abundance of clade D *Symbiodinium* in corals following bleaching events (Rowan 2004; Chen et al. 2005; Jones et al. 2008). In fact observation of clade D seems to be a manifestation of coral recovering from a bleaching event and therefore represents survival strategies (Stat and Gates 2011). In Tanzania, *Symbiodinium* clade D is found in Acropora samples collected from Kitutia (39°45′6.16″E, 8°1′1.87″S) reef, located off the Mafia Island. Such encounter can be explained by history of bleaching events (Chauka et al. in press). Therefore, only reefs off Mafia Island which have been experiencing seasonal bleaching indicate some development of adaptations to bleaching. Generally, most coral genera that have been found to host *Symbiodinium* clade D in other parts of the world have not been found to host clade D on the Tanzanian coast. The inability of most reef building corals species along the Tanzanian coast to host clade D *Symbiodinium* type that has been possible in other part of the world is an indication of low adaptation to climate change.

Endosymbiotic Flexibility

Flexibility in coral-*Symbiodinium* association is hypothetically believed to enable corals to adapt to climate change (Baker 2003). According to Rowan and Knowlton (1995),

Table 2 Examples of coral genera which have been found to form symbiosis with more than one Symbiodinium types as compared with symbiosis occurring in Tanzanian corals-Symbiodinium symbioses

Coral genera	Polymorphic symbioses observed in different parts of the world	*Symbiodinium* types found to associate with mentioned coral genus in Tanzania
Acropora	C3u, C3z, C101, C94, D1-4, D2 (LaJeunesse et al. 2010)	C3u, C3z, C109a, C109b, C115 and D1a (LaJeunesse et al. 2010; Chauka 2012)
Fungia	C3u, D1 (LaJeunesse et al. 2010)	C3u (LaJeunesse et al. 2010; Chauka 2012)
Platygyra	C3u, C101a, C101, D1, D1-4 (LaJeunesse et al. 2010)	C3u (LaJeunesse et al. 2010; Chauka 2012)
Symphyllia	C3u, D1 (LaJeunesse et al. 2010)	C3u (LaJeunesse et al. 2010; Chauka 2012)
Favites	C3u, C3z, C101, D1, D1-4 (LaJeunesse et al. 2010)	C3u (LaJeunesse et al. 2010; Chauka 2012)
Pavona	C3u, D1 (LaJeunesse et al. 2010)	C3u (LaJeunesse et al. 2010; Chauka 2012)
Montastraea	C3u, C101, D1-4 (LaJeunesse et al. 2010; Fabricius et al. 2004)	C3z (LaJeunesse et al. 2010; Chauka 2012)
Goniopora	C1, C3u, D1, D4-1, D5 (LaJeunesse et al. 2010)	C1b-s (LaJeunesse et al. 2010; Chauka 2012)
Poccilopora	C1c, C1d, C1-d, C1d-t, C42a, D1, D5 (LaJeunesse et al. 2010)	C1h (LaJeunesse et al. 2010; Chauka 2012)
Montipora	C15, C110, C26a, D5 (LaJeunesse et al. 2010)	C17, C17a (LaJeunesse et al. 2010; Chauka 2012)
Porites	C15, C114 (LaJeunesse et al. 2010), C & D	C15 (LaJeunesse et al. 2010; Chauka 2012)
Stylophora	C1, C8a (Fitt et al. 2009)	C105a (LaJeunesse et al. 2010; Chauka 2012)

Uppercase letters indicate clade while numbers represent ITS-2 DGGE type

some corals have the ability to get rid of their stress-intolerant *Symbiodinium* and let their tissues be dominated by stress-tolerant *Symbiodinium* type. Empirical data by Baker et al. (2004) shows a possibility of secondary acquisition of symbionts when populations of *Symbiodinium* type in the respective coral tissue are very low. Moreover, recent works show that most bleaching susceptible corals have been found to form symbiosis with different *Symbiodinium* types depending on the environment they are exposed to (Putnam et al. 2012). Likewise, a recent study shows specificity in coral-*Symbiodinium* symbioses to be rare than previously suggested (Silverstein et al. 2012). In most corals species that have shown flexibility in making symbiosis with different *Symbiodinium* partners, shuffling of *Symbiodinium* populations to maximise their survival potential is also possible. In other part of the world, a number of coral genera including *Acropora*, *Platygyra, Goniopora, Favites*, *Pocillopora*, *Symphyllia* are the most flexible in terms of partnership with different *Symbiodinium* types (Table 2). However, except *Acropora*, these genera form symbiosis with single *Symbiodinium* type on the Tanzanian coast (Table 2).

On the Tanzanian coast, the genus *Acropora* was found to establish symbiosis with six different *Symbiodinium* types (Table 2). In most cases however, local environment differences, mainly light micro-environments, played a role in such polymorphic symbioses. For example, in Zanzibar, samples of *Acropora* collected in very turbid reefs were found to establish symbiosis with many symbiont types than in reefs that were clean. Coral-*Symbiodinium* polymorphic symbioses in most part of the world seem to be associated with harsh environment including temperature (Mostafavi et al. 2007; LaJeunesse et al. 2010; Stat and Gates 2011). For example, reef corals in Andaman Sea and North-eastern Indian Ocean, where SSTs are extremely higher; most coral genera were found to establish symbiosis with multiple *Symbiodinium* types (LaJeunesse et al. 2010). Probably exposure of corals colonies to extremely higher SSTs and solar radiations that largely fluctuate seasonally has induced development of adaptations that caused co-existence of different *Symbiodinium* types in the same coral tissue. Genus *Porites* has been found to maintain its C15 *Symbiodinium* type in most part of the world (LaJeunesse et al. 2003, 2004a, 2004b; Stat et al. 2006). However, in the Persian Gulf in Iran where SSTs are extremely high, *Porites* has been able to establish symbiosis with multiple *Symbiodinium* types including clade D (Mostafavi et al. 2007). Inability of most Tanzanian reefs corals to associate with multiple *Symbiodinium* types including thermo tolerant symbionts reflect relatively stable and low temperatures and solar radiations as compared to other reefs that experience seasonal fluctuation of temperature and solar radiations. In case of events that are accompanied by sudden change rise in SSTs and solar radiation, the reef building corals may be severely affected by bleaching compared to those which has experienced such event over long time and be able to establish multiple symbioses.

Concluding Remarks and Future Work

Current predictions show expected rise in temperature of up to 3°C per century (IPCC 2001; Hoegh-Guldberg et al. 2007). Unless appropriate measures are put in place, such a rise is expected to increase frequencies of coral bleaching events which could lead to significant reduction in coral reefs worldwide in this century (Hughes 1994;

Hughes et al. 2003; Hoegh-Guldberg 1999; Hoegh-Guldberg et al. 2007). With evidences provided in this review, Tanzanian coral-*Symbiodinium* symbioses do not favour survival of corals especially in the context rise in sea surface temperatures. Survival rate of corals is also reduced by extremely high anthropogenic pressures from overfishing, pollution, and sedimentation. Because of this, protection and restoration are recommended as management options that will increase survival of Tanzanian coral reefs ecosystem. Such increased survival rate may give room for coral species to develop functioning adaptations strategies before they succumb to elevated sea surface temperature and solar radiations. On one hand, protection would lead to reduction in direct anthropogenic threats from destructive fishing and increase in herbivore fishes that are ecologically important in controlling alga pressure on corals. On the other hand, restoration may selectively lead to increase in bleaching resistant coral species for the survival of ecosystem. This work will not only benefit the corals themselves, but the mangroves, estuaries and see grass ecosystems because of their ecological interdependence.

The review shows that, most Tanzanian corals maintain their *Symbiodinium* types across the country. Probably, the reefs across the country are genetically connected. Reef building corals genetic connectivity study will provide insights on reasons for stability in coral-*Symbiodinium* symbioses along the Tanzanian coast. Likewise, such study will reveal the reefs whose coral populations are affected by others and those reefs whose regenerations depend on local coral population. To help in the survival of those reefs whose regeneration depend on local coral population because their genetical isolation, local management is the best options. This review paper therefore recommend a comprehensive reefs genetic connectivity study along the Tanzanian coast is necessary to provide information on how reefs are connected along the Tanzania coast.

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