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A Questionnaire-based Consideration of Coral Farming for Coastal Socio-economic Development in Mauritius

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Abstract—Mauritian coral reefs, like those elsewhere, sustain a large proportion of the population. Continued demographic growth in Mauritius and the growing consumption of natural resources have resulted in unsustainable exploitation of reef resources, exacerbated by climate change and increasing tourism. The reefs are degraded and, to reverse this process, it is vital that locals, including fishing communities, be involved in active reef restoration. A multiple-choice questionnaire was thus completed by 500 respondents to investigate socio-economic trends and options for reef restoration in five Mauritian coastal regions: Grand Baie, Albion, Flic-en-Flac, Belle-Mare and Blue Bay. A site near a fish farm at Point-aux-Feuilles where corals were cultured was also included. The survey revealed that the respondents were aware of the anthropogenic threats to their marine environment and of the need for active reef rehabilitation. They also indicated that the majority of the coastal communities were willing to participate in community-based coral reef restoration. Additionally, fish farms were deemed preferable sites for coral nurseries due to the availability of facilities, a local work force and good water supply. A call is made for direct local community involvement in eco-business and restoration projects in terms of the Mauritian Ocean Economy initiative which prioritises natural assets.

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INTRODUCTION

The Republic of Mauritius is a tropical island state of volcanic origin in the southwest Indian Ocean, 1860 km^2 in area, a coastal length of 322 km and lagoonal area of ~243 km^2. It has a population of 1.3 million residents, topped by a growing number of tourists who are attracted to its blue lagoons, white sands and rich marine biodiversity, including the coral reefs. The tourism sector is thus an important source of employment and revenue (Turner *et al*., 2000; Daby *et al*., 2002) and, in consequence, the country has been enjoying rapid development over the last decade. Heedless tourism-related development has subjected the Mauritian coral reefs to anthropogenic damage (Wilkinson, 1998, 2008), this despite the fact that lagoons and the coast, from the high water mark up to 81.21 m (Pas Géomètriques Act, 1895; Mauritius Law), constitute a regulated zone and are thus managed by government authorities. As tourism is becoming an ever greater component of the Mauritian economy (two million tourists are expected p.a. by 2015 compared to the current 900 000 tourists/ year), reef degradation will become of greater relevance. The reefs furthermore suffered the effects of coral bleaching after the 1998 El Niño Southern Oscillation Event (Moothien Pillay *et al*., 2002). The consequences of anthropogenic reef deterioration (from agricultural, industrial and urban run-off, eutrophication, overfishing, sand mining and coastal tourism; Turner *et al*., 2000; Daby *et al*., 2002; Ramessur, 2002) have thus attracted increasing attention from government agencies, privately-owned hotels and NGOs, all advocating rehabilitation of this important resource.

The goods and services of Mauritian coral reefs are clearly critical to the social and economic welfare of the country's coastal communities (Turner *et al*., 2000). They provide coastal protection against wave action and erosion (Persand, 2005) and they sustain a large proportion of the population, as occurs elsewhere in the Indian Ocean (e.g., Gomez, 1997; Latypov, 2006). In the latter regard, Mauritian coral reefs are heavily fished and are manifesting the consequences of damaging fishing practices, resulting in dwindling catches (Annual Report Fisheries, 2007; Wilson *et al*., 2008). Recent surveys have also shown that some coral species on Mauritian reefs are threatened with local extinction (Moothien Pillay *et al*., 2012). It is thus vital that fishing communities (including the women) be involved in any actions designed to reverse coral reef degradation and improve reef management (including reef restoration). The long-term sustainability of coral reefs necessitates, therefore, an integrated socio-ecological approach, encompassing the full spectrum of socio-economic and ecological interactions with the coral reefs (Bellwood *et al*., 2004). At present, less than 1% of the reefs are protected from fishing (McClanahan *et al*., 2008), so such actions may well alleviate coastal conflict and boost the economy of the poorer communities. A better understanding is thus needed of the complex socio-economic interactions that influence the way people use and govern their coral reefs.

The link between coastal poverty and reef degradation has prompted new approaches in coastal zone development, one of which is community-based coral farming in Mauritius and Rodrigues (Rinkevich, 2005, 2006, 2008). This has been promoted and instituted in some countries (Salm *et al*., 2000), together with other forms of community-based coral reef resource use (e.g. fisheries, ecotourism, coral trade; Johannes, 1998; Kiss, 2004) introduced to coastal management (Johannes, 1998, 2002). Such approaches are based on the principle that biodiversity should 'pay' for itself by generating economic benefits, particularly for local stakeholders. *In situ* coral farming can successfully be employed in community-based marine resource management (Johannes, 1998), and is easily implemented through asexual propagation or 'fragmentation' of corals (Rinkevich, 2000; Shafir & Rinkevich, 2008, 2010). Farmed coral colonies can be used in reef rehabilitation for coastal protection, improved tourism and resale to the marine aquarium trade (Elis, 1999; Green & Shirley, 1999; Heeger *et al*., 1999; Epstein *et al*., 2001, 2003). It can be an economic driver to improve coastal livelihoods.

The Mauritius Oceanography Institute has, since 2008, been engaged in coral farming projects with promising results on the survival and growth of ten coral species in land- and ocean-based nurseries (Moothien Pillay *et al*., 2012). A joint Mauritius Oceanography Institute and University of Mauritius study focused on the effects of artificial feeding and environmental conditions on the *in situ* growth of cultured coral fragments in 2010 (Nazurally, unpubl. data); the fish farm at Point-aux-Feuilles where nutrient levels are high was included in the investigation. Notwithstanding their slow growth, corals may exhibit high calcification rates in such nutrient-rich environments (Shafir & Rinkevich, 2008, 2010) and the best results were obtained at the fish farm nursery (Nazurally, unpubl. data). Another coral farming pilot project was implemented in 2008-2010 by the Ministry of Fisheries and Rodrigues in the Albion lagoon and, more recently, at Rodrigues Island. The present study was thus undertaken to assess the current socio-economic outlook on 'coral farming' using a multiple-choice questionnaire, targeting the concept of community-based coral aquaculture in Mauritius and querying preferred farming sites for such a nursery.

MATERIALS and METHODS

We developed a composite index to target population awareness vis-à-vis 'coral farming', residents' willingness to participate in community-based coral farming for reef rehabilitation and in eco-businesses and potential sites for coral nurseries.

Questionnaire and survey sites

An undisguised questionnaire of 35 questions (25 multiple choice and ten qualitative questions) was compiled in four sections, targeting: 1) familiarity with coral reefs; 2) knowledge of coral farming; 3) the availability of local community manpower for coral farming; and 4) respondent profile. The questionnaire was designed such that consecutive questions would not bias each other (based on Choi & Pak, 2005). The questionnaire included several general questions on respondent educational level, occupation/s, family size, income, familiarity with coral reefs and knowledge of threats to marine biodiversity. Coral farming was interrogated based on a respondent's experience and perceptions of coral reefs, with questions scaled on a 5-point rating in a semantic differential employing two bi-polar adjectives as the extremes.

Targeted participants in the survey were local residents at five locations in Mauritius (Grand Baie, Albion, Flic en Flac/Le Morne, Belle-Mare and Blue Bay; representing regions in the north, west, east and south of Mauritius, respectively; Fig. 1). Sites were chosen based on the existence of coastal infrastructure, including commercial and tourism facilities, and their proximity to local communities, all of which could potentially support coral farming. We included the fish farm at Point-aux-Feuilles (Fig. 1) since coral farming already occurs there. In addition, we reviewed Mauritian documentation in which coral reef rehabilitation is discussed, including scientific literature, grey literature and hotel EIAs (Environmental Impact Assessments).

Mauritius has a diverse, multi-lingual society and this was taken into account by interviewing the respondents in their own language. The questionnaires were distributed by educated local residents, providing interviews without language bias, and taking into consideration respondent age, educational level and cultural background.

Data analysis

The survey data were analysed using the Statistical Package for the Social Sciences (SPSS) and Microsoft Excel software. Eight key environmental and anthropogenic parameters were also qualitatively compared at the study sites within a range of evaluators between 8-40. These comprised reef status at the sites, the impacts of human activities at the sites and their suitability for the present and proposed activities.

RESULTS and DISCUSSION

Site overview

Grand Baie lies in north Mauritius with an area of about 5.5 km^2 and ca. 15 000 inhabitants. It is an international tourist destination but rapid, unplanned development has resulted in Grand Baie becoming overcrowded with hotels, restaurants, nightclubs, residential buildings, bungalows and commercial development with numerous boats mooring in the lagoon. In addition to direct anthropogenic damage, heavy rainwater runoff has further deteriorated the beaches as the wetland at Grand Baie has undergone urban development (The Watershed Company, NWFS Consultancy, 2008). Diving centres and tourism development are increasing along the coastal road of Grand Baie, contributing to the pressure on its already degraded shoreline. The reefs around Grand Baie are a high priority for rehabilitation but these anthropogenic pressures must be taken into account, and in any consideration of a coral nursery.

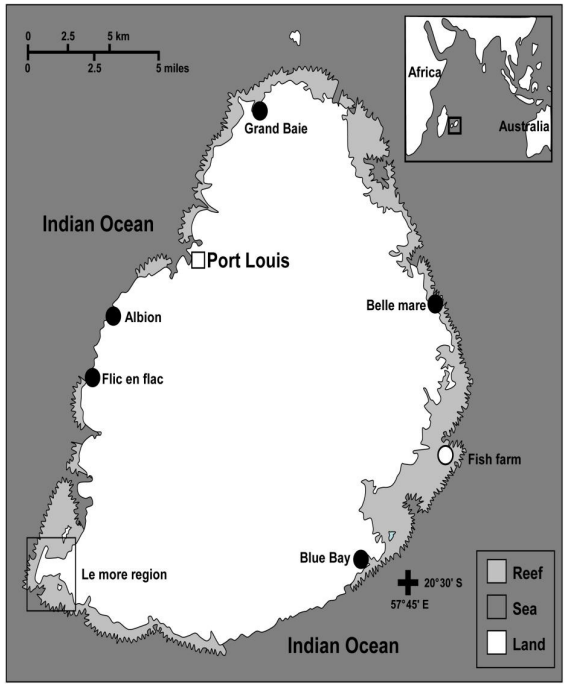

Figure 1. The five sites and the fish farm located at Point-aux-Feuilles assessed for community-based coral farming.

Albion is in the west of Mauritius with an area of about 5.0 km^2 and ca. 5 200 inhabitants. It has witnessed the development of lodges for foreign and local tourists over the past five years and is the fastest growing Municipal Ward/Village Council Area in Mauritius, growing in population by 85% from 2000 to 2011 (Mauritius Central Statistics Office, 2000 & 2011). It has a very shallow lagoon (the corals are exposed at low tide) and is fished by local communities; these attributes combined with the hotel developments make the reefs vulnerable to damage. As a result, condition of the reefs has been deteriorating in recent years and some areas are completely destroyed. The Mauritius Oceanography Institute established a pilot coral nursery/ farming near the channel of Albion lagoon in 2008 that has proved promising (Moothien Pillay *et al*., 2012). Albion is thus a potential coral nursery site with limited advantages that could assist in reef rehabilitation.

Flic en Flac, located in the west of Mauritius, has an area of about 15.50 km^2, ca. 17 000 inhabitants, and is prized by both Mauritians and tourists for its long beaches, recreational amenities (diving, snorkelling, kite surfing and recreational boating), high class hotels, restaurants, night clubs, residential buildings and bungalows. It is under intense anthropogenic pressure. The beach at Flic en Flac has been reduced by erosion (Baird, 2003), adding to anthropogenic damage on the coral reefs in the lagoon through increased sedimentation. This has made it unsuitable for a coral nursery but rehabilitation of its reef system is deemed vital. Stabilization of the shoreline will have to be accomplished first.

Belle-Mare is on the east coast of Mauritius, with an area of about 3.1 km^2 and ca. 15,000 inhabitants. It is one of the most beautiful of Mauritian beaches, characterized by pure white sand and has a reef with high a diversity of corals, marine invertebrates and fish. It attracts fishermen and is well-known for its recreational activitites like an underwater trail, SCUBA diving, parasailing, water-skiing, kayaking and other water sports, and is therefore frequented by a

high number of tourists and Mauritians. Intensive onion cultivation along the coast, supported by the heavy use of fertilizers and pesticides, affects the marine environment (Daby *et al*., 2002), causing high algal blooms. The hospitality industry in the area is actively involved in community welfare through Corporate Social Responsibility programmes and generates funds for green endeavors. Belle-Mare thus has potential for a coral nursery due to community willingness, which could be boosted by start-up funds from the hospitality industry. Furthermore, Belle-Mare is protected from strong waves and its lagoon has clear water with a maximum depth of 8 m.

Blue Bay, in the south east of Mauritius, is over 3.5 km^2 in area with ca. 12,000 inhabitants, and lies in a marine park (bordering the runway of the international airport) offering some of the best snorkelling on the island. The park includes the lagoon and extends ~1 km seaward from the reef crest. Blue Bay Marine Park has >50 coral species, many fish species, mangroves, seagrasses and a high diversity of marine invertebrates. Most of its flora and fauna have suffered in one way or another from anthropogenic pressure and climate change. A coral nursery in Blue Bay would experience problems due to the high traffic in the marine park.

The **Fish Farm** at Pointe aux Feuilles lies in an area occupied mostly by coastal communities and fishermen. It was considered a reference location to evaluate the potential for coral nurseries in Mauritius and has a history of coral farming (Bongiorni *et al*., 2003, 2011; Shafir *et al*., 2006; Shafir & Rinkevich, 2008, 2010) with high growth rates in nurseries located near fish farms. Pointe aux Feuilles has the only operational lagoonal fish farm in Mauritius, which could be an ideal site for establishing a regional coral nursery, following studies (Shafir *et al*., 2009; Shafir and Rinkevich, 2008, 2010; Bongiorni *et al*., 2011) indicating increased coral growth and health in nutrient-enriched waters near fish cages. The water at the fish farm is up to 30 m deep and a mid-water coral nursery would be advantageous at this depth as, in cyclonic conditions, the nursery can be submerged to protect the facilities and coral fragments.

Results of the preliminary assessment of the selected Mauritian sites, taking into consideration the range of local conditions (physical, environmental, social) and potential for coral farming, are presented in Table 1. Overall, the fish farm area proved the most appropriate place for a mid-water nursery (Table

Table 1. Qualitative assessment of the suitability of the study sites for coral nurseries.

Site	Parameters								Total score
	*Reef Status	**Population density	*Human impact	*Tourism impact	*Agricultural impact	**Reef accesibility	**Infrastructure	**Diving or snorkelling sites	
Grand Baie	3	3	3	1	5	1	2	3	21
Albion	1	3	1	3	5	5	1	2	21
Flic en Flac	3	2	3	3	5	5	3	3	27
Belle-Mare	2	2	3	3	2	5	3	3	23
Blue Bay	3	3	3	4	5	4	3	3	28
Fish farm	1	5	5	5	5	2	5	5	33

* Environmental parameters: 1 = degraded/highly impacted site, 5 = relatively pristine site
** Site suitability for coral farming: 1 = inappropriate, 5 = very suitable

Table 2. Number of survey participants in the different age groups.

Age group	Grand Baie	Albion	Belle-Mare	Blue Bay	Flic en Flac	Total
< 20	1	15	18	21	15	70
20-40	67	75	77	45	43	307
41-50	30	9	2	23	35	99
51-65	1	1	1	11	7	21
>65	1	0	2	0	0	3
Total (n)	100	100	100	100	100	500

1; scored 33), followed by Blue Bay (scored 27); Grand Baie and Albion (scored 21) were found the least suitable (Table 1). In addition, we found that the shallow reef (<2 m deep) 200 m from the fish farm was a good site for restoration.

Questionnaire

The response rate to the questionnaire survey was high (86%). Overall, 500 questionaires were completed, 100 at each of the five study sites, the respondents being 35% male and 65% female, and the majority falling between the ages of 20 to 65 years (Table 2). Participants in the age group 20-40 (61.4%; Table 2) cooperated enthusiastically, while fewer participants <20 and >50 years were keen to be interviewed and very few >65 years old.

Most survey participants in the age group 20-40 (31.6%) were employed in the tourism industry. About 10% of this age group were educated to the School Certificate level and about 5% to Certificate of Primary Education (CPE) level. The income of the participants ranged from <Rs5 000 (29%; Table 3) to Rs30 000, with only 10% receiving salaries of Rs20 001-30 000 (Table 3).

Table 3. Approximate monthly income of the survey participants (Rs31 = $1).

Income (Rs)	%
<5 000	29
5 001-10 000	38
10 001-20 000	23
20 001-30 000	10
>30 001	0

Knowledge of coral reefs

The majority of Mauritians interviewed claimed to be familiar with coral reefs (considerable, 20%; good, 27%; moderate, 37%; low, 12%; and negligible, 4%). Few were SCUBA divers (3%), many participants being snorkelers (35%) and most non-divers (62%). However, most were conscious of potential threats to the marine environment and could differentiate between the threats listed in the questionnaire. Most survey participants were concerned about coral reef degradation (25%) and biodiversity loss (20%), and considered beach erosion (19%), mangrove deforestation (12%) and unplanned development (10%) to be the major culprits for degradation of these natural assets (Fig. 2). Only a few suggested marine pollution, global warming and sea level rise to be major causes of reef degradation in Mauritius (14%; Fig. 2).

Coral farming

The term coral farming was understood by only 23% of the survey participants, but they had heard about coral farming, mostly from newspaper articles and documentaries. All participants agreed that a healthy coral reef is the foundation needed for a healthy fish catch. Following more detailed queries on the meaning of ‘coral farming’, most interviewees responded positively and expressed a willingness to cooperate in community-based coral farming for conservation without knowing its full connotations. Many interviewees (48%) were reluctant to identify business prospects as a major motive for coral farming. About 86% of the survey participants

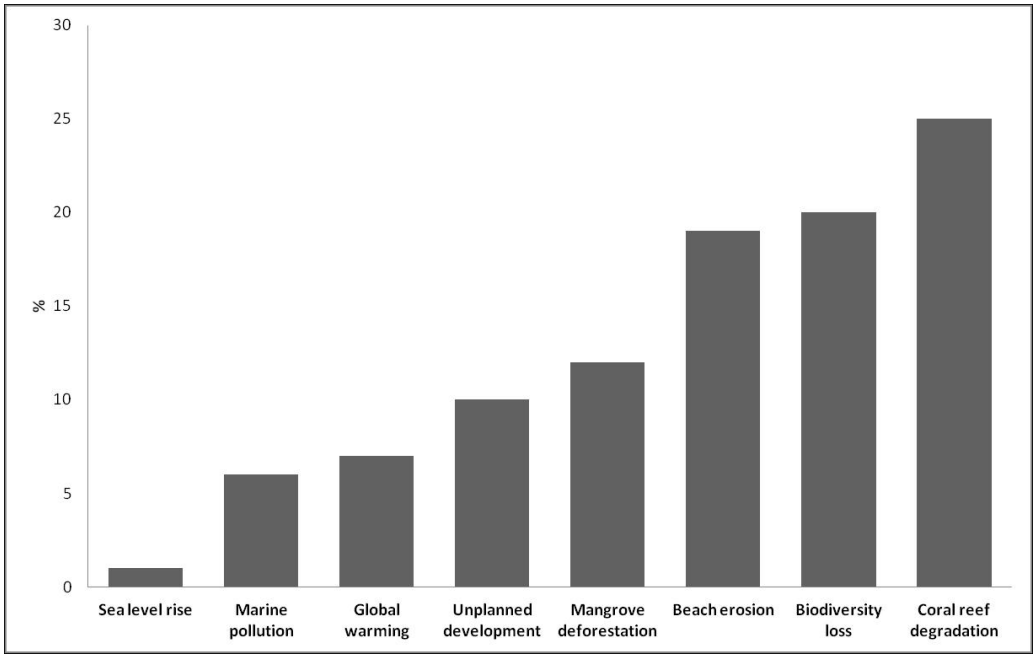

Figure 2. Survey participant attribution of causes to coral reef degradation and biodiversity loss.

agreed with the principle that biodiversity should 'pay' for itself by generating economic benefits. Participants were also keen to build or buy saltwater aquariums, even though they lacked experience and knowledge, but 89% would have liked to take a course in saltwater aquarium keeping and 80% expressed willingness to pay for such course.

Community-based coral farming

The survey results showed that 21.9% of the participants had a basic knowledge of community-based coral farming and believed it could provide an alternative means for income, but about 95% (n=475) of them were unaware that community-based coral farming occurred elsewhere in the world. Willingness to participate in community-based coral farming was expressed by local communities, 98% (n=490) of them noting the need for training. Only 2% (n=10) were reluctant to get involved, particularly if snorkeling or diving might be involved.

The questionnaire results indicated clear willingness by respondents to cooperate in active reef restoration, which would render reef resources more sustainable for the coastal communities. Respondents felt that locating a coral nursery near a fish farm would make it easier to establish.

Potential for a coral nursery

Community-based coral farming would be consistent with Mauritian government policy to turn the island into an 'Ocean Economy' (an initiative that prioritizes natural assets, in this case shifting usage of Mauritian reefs from "extraction and exploitation" to a "development space" based on sustainability). Several sites were thus identified for the aquaculture of various marine species (Ministry of Agro Industry and Fisheries, 2007), including corals to be used for reef restoration (Nazurally, unpubl. data). Such a move would support the future of the tourism industry in Mauritius as reef rehabilitation

will enhance ecosystem services for tourism, fisheries and coastline protection (Moothien Pillay *et al*., 2012). Potential support for this by the hospitality industry has already been noted, making the cost of developing coral farming more feasible.

The present results give reason to believe that the fish farm area at Pointe aux Feuilles village would be the best site for a regional mid-water coral nursery, especially in view of the morphology of the lagoon in which it is situated which provides protection from the cyclones that frequently hit Mauritius. The lagoons at the other potential five sites are very shallow and prone to incidents of elevated sea surface temperature during summer.

In conclusion, the results of the study revealed that the greater proportion of the local communities surveyed would be interested in community-based coral farming, believing that it will generate additional income to sustain their families. Poor coastal communities do not fully benefit from the tourism industry (Table 3); their livelihood is still heavily dependent on natural resources and on subsistence farming and community-based coral farming could present an alternative livelihood. The involvement of women could play an important role in such a venture (Heeger *et al*., 1999). Overall, it could enhance existing natural resource management and improve reef biodiversity and the Mauritian economy.

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